TECHNICAL REPORT

The Department of Defense and Climate Change: Initiating the Dialogue

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THE DEPARTMENT OF DEFENSE AND CLIMATE CHANGE: INITIATING THE DIALOGUE

A WORKSHOP TO INFORM FUTURE COORDINATION WITHIN THE DOD RESEARCH COMMUNITY AND BETWEEN THE RESEARCH AND POLICY COMMUNITIES

PROCEEDINGS AND RECOMMENDATIONS

January 2012

Workshop convened July 19−21, 2011, Aurora, Colorado

**Workshop planned by and report prepared by the Office of Naval Research,
Strategic Environmental Research and Development Program,
U.S. Army Corps of Engineers, Engineer Research and Development Center, and
Office of the Oceanographer of the Navy, Task Force Climate Change**

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PREFACE

For the Department of Defense (DoD) the implications of climate change and associated climate variability permeate all aspects of the Department's missions and responsibilities: operational, military readiness, maintaining infrastructure to support the mission, compliance, and stewardship. Although from one perspective climate change is simply an added stressor layered atop already existing stressors, its broad reach, tendency to exacerbate the effects of other stressors, and in some cases its capability to lead to irreversible changes in physical and biological systems compels a new way of responding to its challenge. The time horizons relevant to climate change processes and impacts to be considered in planning and decision making become extended—perhaps significantly. Rather than addressing the implications of climate change as an isolated policy and management concern, it may be more effective to weave its issues into any number of existing planning documents and decision processes. The risk envelope, including associated degrees of uncertainty, that must be considered in view of climate change is greatly expanded. Most importantly, the complexity of climate change and the potential costs of risk management actions, or even no action, compel an adaptive decision making framework that includes establishing and sustaining a process and dialogue involving policy makers, end users, and the research community. Such an ongoing dialogue can assist DoD policy makers in understanding the nature of decisions potentially affected by climate change, their spatial and temporal domains, and the appropriate climate change scenarios and climate-related information—informed by the best available science—to consider when making a range of decisions. Moreover, it provides an avenue of assessing and managing the potential regret of inaction to avoid sustained, severe, and widespread impairments to DoD missions. To start this dialogue, and to help frame a path forward, several organizational elements of DoD's research and development community convened a workshop in July 2011 involving both DoD researchers and policy makers, as well as other key elements of the federal climate change research and climate services community. This report represents both a synopsis of the workshop discussions, as well as a synthesis of ideas arising from the workshop that are offered in the spirit of moving the dialogue and the development of relevant technical capabilities forward.

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EXECUTIVE SUMMARY

Department of Defense (DoD) policy calls for a strategic approach to the challenges posed by global climate change and climate variability. The February 2010 Quadrennial Defense Review recognized that climate change will affect the Department in two broad ways:

- First, climate change will shape the operating environment, roles, and missions that DoD undertakes.
- Second, the DoD will need to adjust to the impacts of climate change on its facilities and military capabilities.

To assist the Department in responding to the above challenges, the focus of this workshop was twofold: first, to establish a DoD network of funding entities and research centers and laboratories involved in climate change-related research and demonstration and second to identify the role that DoD's research and development (R&D) community could serve to (1) assist DoD policy makers by providing the technical foundation for advancing new policies related to climate change and (2) provide DoD resource, infrastructure, and operational managers the needed science information, models, and tools needed to implement the effects of policy "on the ground." The workshop emphasized that climate change, including changes in climate variability, should be viewed in the broader context of global change phenomena that affect the ability of DoD to accomplish and sustain its missions into the future.

The workshop included a workshop introduction, plenary sessions, and breakout sessions. Plenary sessions included briefs from federal non-DoD participants regarding the US Global Change Research Program, National Climate Assessment, and the emerging effort at the federal level to provide climate information services and how DoD may relate to this activities. Policy perspectives on the role of and need for climate change science were provided by the Office of Secretary of Defense (OSD), military Services, and US Army Corps of Engineer Civil Works representatives during additional plenary sessions. Facilitated breakout sessions occurred on each of the three days of the workshop. These sessions enabled assessing climate change information needs from a number of different perspectives.

Workshop participants noted that specific step-down policy and guidance regarding climate change vulnerability, impact, or risk assessment and adaptation generally has yet to be issued at the Department level. This includes but is not limited to defining bounding assumptions and their temporal and spatial scales, such as sea level change, climate change, and extreme event scenarios, to guide vulnerability, impact, and risk assessments, as well as development of adaptation strategies and actions. As a result, the plenary sessions and policy panel discussion highlighted the need for and challenged the DoD R&D community to assist with providing technical support to the policy community that would meet their needs. Besides defining the technical bounds of policy-relevant information related to climate change, workshop participants also noted that the R&D community has a responsibility to translate the implications of the science and technology needed by policy makers and to provide the end-user (installation managers and operational units) with actionable information.

The Department possesses a range of science and engineering capability relevant to understanding and analyzing the vulnerabilities, threats, and risks that climate change poses to DoD assets, infrastructure, and future missions. Future development and coordination of this

capability, across OSD, the Services, and the Corps Civil Works program will enable DoD to capitalize on its corporate technical capacity and effectively leverage the technical capacity in other agencies and organizations.

Workshop participants developed an initial blueprint for a DoD climate change research agenda. Research needed to support DoD's response to climate change involves both fundamental and applied science, as well as translation of that science into actionable information for policy makers and end-users. On a thematic basis, research and translation needs can be divided into climate system modeling, physical forcings and environmental process modeling, assessment and adaptation methodologies/strategies. DoD's R&D community will often not be the primary provider for all research needs, but will still serve a vital role in fulfilling DoD-specific research and translation needs. DoD sponsored research should be responsive to user-defined needs.

Policy and guidance have yet to be firmly established to support both tactical and strategic planning in the face of climate change. What the Department needs is a robust, scientifically defensible approach that transparently communicates risks to the end-user and helps policymakers develop guidance to promote mission sustainability in the face of climate change. Although R&D on built and natural infrastructure response to climate change has progressed in recent years, a coherent vision of installation and operational military vulnerabilities has not been compiled. Policy awareness is emerging, but its growth and maturity to meet both strategic and tactical DoD needs would be best served by an ongoing and interactive dialogue between the policy and R&D communities. Adaptive, risk-based decision frameworks that assess vulnerabilities, impacts, and risks, as appropriate, are needed and should be developed jointly and iteratively between the R&D and policy communities to incorporate climate change into tactical and strategic planning activities, with prioritization based on the types of decisions to be made and their spatial and temporal aspects.

The workshop resulted in five primary recommendations:

1. The Department, inclusive of the military Services and U.S. Army Corps of Engineers, Civil Works program, has an ongoing need to assess the state of the science, practice, and policy needs relative to understanding the mission challenges raised by climate change and the framing of appropriate responses to such challenges, including their spatial and temporal aspects.
2. The DoD R&D and policy communities should establish those mechanisms necessary to maintain an ongoing dialogue.
3. To support DoD's Climate Change Adaptation Planning Task Force—whose establishment by OSD(Installations & Environment) is underway—DoD should consider establishing a DoD Climate Change Science Technical Workgroup that can interact directly with the Task Force on matters of climate change science-policy intersection. At least one member of the Workgroup should be a member of the Task Force and serve a liaison function.
4. The DoD R&D community must provide defensible science, models, and tools to support DoD and the Services' needs regarding climate change and extreme event forecasting ability to meet operational needs, vulnerability and impacts assessments based on robust climate change scenarios, adaptation science, and mitigation.
5. We do not have the resources to respond to the challenge of climate change alone. DoD should establish new and strengthen existing relationships with the federal R&D community, in part by participating in inter-agency research coordination efforts, to leverage resources, avoid redundancy, and highlight the Department's research needs.

1 INTRODUCTION

Department of Defense (DoD) policy calls for a strategic approach to the challenges posed by global climate change and climate variability. The February 2010 Quadrennial Defense Review (QDR) recognized that climate change will affect the Department in two broad ways:

- First, climate change will shape the operating environment, roles, and missions that DoD undertakes.
- Second, the DoD will need to adjust to the impacts of climate change on its facilities and military capabilities.

The QDR also recognized that DoD must develop policies and plans to manage the effects of climate change on its operating environment, missions, and facilities, including addressing the potential impacts to DoD natural and built infrastructure at permanent installations that support DoD's national security mission and to adapt as required. And finally, the QDR highlighted the need for DoD to regularly reevaluate climate change risks and opportunities and to work collaboratively with outside partners to meet the challenges posed by climate change.

In addition to DoD policy, Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, directed Federal agencies to assess both their vulnerabilities to climate change and the need for possible adaptation strategies. This EO, among many of its provisions, established the Interagency Climate Change Adaptation Task Force and mandated that each agency develop, implement, and annually update a Strategic Sustainability Performance Plan (SSPP). The required content of the SSPP compelled each agency to initially articulate how it would "evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency's operations and mission in both the short and long term." The initial DoD SSPP was submitted to and approved by the Council on Environmental Quality (CEQ) during the summer of 2010.

More recently, under the authority of EO 13514 the CEQ issued Federal Agency Climate Change Adaptation Planning Implementing Instructions in March 2011 that mandated each agency submit, concurrent with their updated SSPP, a separate Climate Adaptation Plan by June 2012. An intermediate step to this plan is a Department-level analysis of key vulnerabilities to climate change due to CEQ by March 2012.

Separate from these policy drivers, but at this point in time uniquely related to these drivers, the DoD is participating as a member agency of the US Global Change Research Program (USGCRP) and on an interagency task force associated with the National Climate Assessment (NCA), which is an every four-year assessment mandated by the Global Change Research Act of 1990 of the state of climate science and the potential impacts of global change, primarily climate change, at the national scale. Both of these efforts enable DoD to air its concerns relative to the effects of global change on its missions and to influence and keep abreast of the state of the science and future research priorities.

With the preceding as a backdrop, the focus of this workshop was first on establishing a DoD network of funding entities and research centers and laboratories involved in climate change-related research and demonstration and second on identifying the role that DoD's research and development (R&D) community could serve to (1) assist DoD policy makers by providing the

technical foundation for advancing new policies related to climate change and (2) provide DoD resource, infrastructure, and operational managers the science information, models, and tools needed to implement the effects of policy "on the ground." The workshop emphasized that climate change, including changes in climate variability, should be viewed in the broader context of global change phenomena that affect the ability of DoD to accomplish and sustain its missions into the future. Specific workshop objectives are contained in the workshop charge, which is included as part of Appendix A1.

The workshop was held July 19 through July 21, 2011 in Aurora, Colorado. This report is a summary of workshop proceedings and resultant findings, implications, and recommendations as developed by the workshop organizers. Workshop organizers included: the Office of Naval Research (ONR), which also was the sponsoring entity; Department of Defense, Strategic Environmental Research and Development Program (SERDP); Navy Task Force Climate Change (TFCC); and US Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC). Workshop participants included both members of the DoD climate change R&D community and Office of Secretary of Defense (OSD), military Services, and USACE Civil Works policy community representatives. Select members of the federal non-DoD research community also participated. The complete list of participants is provided in Appendix B.

The workshop included a workshop introduction, plenary sessions, and breakout sessions (see the complete workshop agenda in Appendix A2). Plenary sessions included briefs from federal non-DoD participants regarding the USGCRP, NCA, and the emerging effort at the federal level to provide climate information services and how DoD may relate to these activities. Policy perspectives on the role of and need for climate change science were provided by OSD, military Service, and USACE Civil Works representatives during additional plenary sessions. Facilitated breakout sessions occurred on each of the three days of the workshop. These sessions enabled assessing climate change information needs from a number of different perspectives that included: Service-specific needs, biophysical region (i.e., coastal environments, cold region environments, and inland and arid region environments), functional area (i.e., vulnerability assessment, impact assessment, adaptation science, and mitigation science). Charges specific to each breakout session are provided in Appendix A3.

The remainder of this report is divided into a series of chapters and supporting technical appendices. Chapter 2 provides brief summaries of the plenary sessions, policy panel discussion, and breakout sessions that highlight the key points and findings. Chapter 3 provides an overarching synthesis of the workshop's main findings and emerging themes, whereas Chapter 4 focuses on the key recommendations for continuing the dialogue between the DoD R&D and policy communities plus other specific recommendations. Appendices include: background information on and summary information from the workshop (i.e., charges, agenda, and breakout session summaries; Appendix A); list of participants (Appendix B); glossary (Appendix C); list of acronyms/abbreviations (Appendix D), DoD R&D organization summaries (Appendix E); a network wiring diagram to facilitate an understanding of how DoD relates to ongoing federal efforts, such as the USGCRP, NCA, and the Adaptation Task Force, and key points of contact within DoD (Appendix F), and breakout session summaries (Appendix G).

2 PLENARY AND BREAKOUT SESSION SUMMARIES

The workshop format consisted of both plenary and breakout sessions. In the sections below, brief overviews of the plenary presentations are provided followed by a synopsis of the breakout session discussions. A more complete description of each breakout session discussion is provided in Appendix G.

2.1 Plenary Summaries

The workshop used several different sets of plenary sessions and a final panel discussion to (1) introduce workshop participants to the purpose and scope of the workshop, (2) provide context as to how the Department of Defense's (DoD) climate change, research and development (R&D) efforts fit into the broader federal enterprise, and (3) provide the perspectives of Office of Secretary of Defense (OSD), military Services, and US Army Corps of Engineers (USACE), Civil Works offices responsible for climate change-related policy development within their respective organizations. Presentations summaries are included within the day that they occurred during the workshop.

2.1.1 Day 1

Dr. Charles L. Vincent (Navy: ONR) and Dr. John Hall (OSD: SERDP/ESTCP)—These speakers delivered the opening welcome to the workshop and provided their perspectives on the purposes of the workshop and what they hoped to achieve. Importantly, they each outlined during their presentations and throughout the workshop their respective organizational roles in representing DoD in regards to the US Global Change Research Program (USGRCP; Dr. Vincent) and the National Climate Assessment (Interagency Task Force and Federal Advisory Committee) and Adaptation Science Workgroup (Dr. Hall). Appendix F attempts to graphically depict these complex organizational relationships. Dr. Hall also presented a conceptual framework for coordination among the R&D, policy, and end-user communities (see section 4.2 for one example illustration).

Dr. Tom Armstrong (USGCRP; via teleconference)—Dr. Armstrong provided an overview of the USGCRP. This included a recounting of its history, vision and mission, its organizational structure and program functions, and a vision for climate services. He then provided a description of the new decadal USGRCP strategic planning effort, including the goal structure of the new plan and the timeline for its preparation, review, and revisions prior to final approval. Dr. Armstrong then concluded with an overview of the National Climate Assessment (NCA).

Ms. Maureen Sullivan (OSD: I&E, Environmental Management)—Ms. Sullivan posed two fundamental questions to the audience that needed to be addressed by DoD in responding to climate change: Focus on what assets? Focus on what scenarios of climate change? She then went on to describe the current drivers for DoD action: the February 2010 Quadrennial Defense Review and the March 2011 Council on Environmental Quality (CEQ)-issued Federal Agency Climate Change Adaptation Planning Implementing Instructions. Ms. Sullivan briefly described DoD assets at risk from climate change and then described the near-term actions that DoD is taking to respond. She concluded with a challenge to the R&D community to identify what they needed from the policy community to assist DoD in rising to the challenge.

Mr. Frank DiGiovanni (OSD: TRS)—Mr. DiGiovanni described the role of his office, why it is concerned with climate change and its potential impact on military readiness, and his goal to pose for the audience some readiness-focused climate change research and development thoughts. He challenged the audience that to be adaptive, including under climate change, one must question the norm and be able to function at high levels of ambiguity [uncertainty]. He summarized some potential range, training, infrastructure, and operational issues and offered that to adapt from a readiness perspective may require new types of training infrastructure and new ways of training. Mr. DiGiovanni posed the question whether the Department's climate change adaptation strategies can draw from human adaptation models. He concluded with a call for developing leading indicators of change regarding impacts to readiness, following an iterative approach to learning that includes robust feedback mechanisms, and solving problems within the correct context—context matters.

Mr. James Dalton (USACE: Engineering and Construction)—Mr. Dalton provided the US Army Corps of Engineer (USACE), Civil Works program perspective on the challenges climate change poses to USACE missions, especially water resource management. He provided an overarching vision that engineers in the Corps must be able to successfully perform their missions, operations, programs, and projects in an increasingly dynamic physical, socioeconomic, and political environment. Climate change has caused a shift in the decision paradigm from equilibrium to dynamic—stationarity is dead. Mr. Dalton then provided an overview of the Corps's efforts to conduct a nation-wide screening-level assessment of vulnerability to climate change across its eight business lines and their pilot adaptation studies. He concluded with a summary of next steps and short list of engineer needs relative to climate change information.

2.1.2 Day 2

CAPT Tim Gallaudet (Navy: Oceanographer of the Navy)—CAPT Gallaudet provided a mini-overview of climate change phenomena and then presented the fundamental challenge: the scientist-public disconnect in the understanding of climate change and what to do about it. He then described the Navy's initial efforts regarding climate change leading to the establishment of Task Force Climate Change in May 2009, their major concerns with respect to climate change impacts, and their current approach for responding. CAPT Gallaudet provided an overview of the Navy's current vision for an installation vulnerability assessment. With respect to Arctic issues and climate change, he indicated that policy development will lead to capability development within the context of how climate change may affect those capabilities.

Mr. Daniel Kowalczyk (Air Force: SAF/IEE)—Mr. Kowalcyzk described the Air Force's approach to planning for climate change. The Air Force is planning for impacts across three broad areas: installations and the built environment; roles, missions, and the operating environment, and natural environment and stewardship responsibilities. Mr. Kowalcyzk outlined the Air Force's manner of addressing climate change through a planning framework focused on four key areas: mitigation, adaptation, collaboration, and education. Their adaptation component included a qualitative vulnerability assessment from the QDR that indicated risk to Air Force installations but perhaps not to the degree of the other Services. He also described a recent projected-climatology tool under development by the US Air Force's 14th Weather Squadron. This tool will enable direct comparisons between climate conditions projected to

occur at installations for the 2030 to 2050 time period to locations that have that same climate today. This will facilitate conceptualization by military planners and policy makers of the impacts potentially occurring under climate change and to better plan adaptive strategies.

Mr. Tom Mooney (Army: ODASA(ESOH))—Mr. Mooney provided the Army's perspective on climate change by first describing the vast amount of assets under Army control and the Army's sustainability vision that also accounts for the challenge of climate change. He then described how the Army has incorporated its strategic response to climate change through its Army Sustainability Campaign Plan, issued May 2010. One task of the plan involves developing guidance for conducting installation/facility level vulnerability and risk assessments to analyze global climate change (GCC) impacts to mission and programming for GCC adaptation and mitigation measures, whereas a second task mandates completing the preceding assessments during scheduled updates of installation/facility-level management plans and programming for GCC adaptation and mitigation measures in future Program Objective Memorandum (POM) cycles.

Panel Discussion (Sullivan, Gallaudet, Kowalczyk, and Mooney)—The panel was posed several questions and the following represents a summary of the unattributed responses and audience feedback. Some bullets may represent the contribution of more than one person when a particular point received comment. The questions ranged from greatest needs to inform policy formulation to how to craft a strategic message on what is important to the role of the joint staff. The responses can be summarized as follows:

- Need basic science information at the regional scale to support vulnerability assessments at the regional and local scales in a manner that is understandable and actionable.
- Need to explain the fidelity of the information developed and used for assessments and planning.
- Maintain technical accuracy but translate information within a comprehensive but accessible context that policy formulators understand.
- Need to have a relationship with the R&D community through the right venues that can facilitate a two-way communication of information.
- New processes not necessarily needed. Need participation in existing mechanisms. Ensure right people connected.
- Need the research arms of OSD and the Services to develop a strategic message on what is important and how to translate the information to interested/affected parties.
- Joint staff ***not*** currently heavily involved in addressing initial climate change challenges, but the concept is of interest and would need Administration support to engage. Perhaps consider initial engagement through J4 (engineer-programs offices).
- Develop scientific questions that need to be answered to make mission decisions; account for the operational needs of the future.
- Possible partners for strategic sustainability: State Department, US Agency for International Development, Combatant Commands, and US overseas embassies. Consider impacts on human populations and likely responses.
- State more clearly by sector:
  - What types of answers are needed to make decisions?
  - Over what timeframe are answers needed?
  - How much uncertainty can be tolerated in solutions?

- Explain climate change R&D needs in terms of DoD priorities:
  - Prevail in current conflicts
  - Prepare for future conflicts.
- Update assets to endure through climate change impacts.
- Context matters in the climate-society interface. Adaptation is a process and not a single decision. Need to develop decision calendars—timelines for decisions.

Dr. Eileen Shea (NOAA, National Climate Data Center)—Dr. Shea's main theme was climate services for society: challenges and opportunities. She began by articulating what an ability to effectively anticipate and respond to climate change requires. Dr. Shea then described how climate change already is affecting society and what it means to adapt to climate change. She then addressed the federal role in adapting to climate change, with an emphasis on meeting the rising demand for climate services and the National Oceanic and Atmospheric Administration's (NOAA) vision for doing so. Dr. Shea then put the issue of climate information provisioning into a broader federal perspective and the recent federal efforts to better coordinate information provisioning and form eight regional hubs that align with the geopolitical regions used by the NCA to conduct regional assessments. She concluded with some shared lessons on meeting stakeholder climate science and service needs.

2.2 Breakout Session Summaries

The workshop used a combination of military Service breakout and thematic breakout sessions to explore climate change information needs. Service breakouts took place on day 1 and the thematic sessions on Days 2 and 3. Synopses of discussions are provided in the following sections. Narratives generally follow the sequence of questions articulated in Appendix A3 for the particular session. See Appendix G for more detailed accounts.

2.2.1 Day 1

Service Breakout: Army/Air Force—The Army and Air Force are both engaged in organizational activities with respect to the generation and use of climate change information. Within the Army, the five elements currently engaged include the Army Installation Management Command (IMCOM), Office of the Assistant Secretary of the Army for Installations, Energy, and the Environment (ASA(IE&E)), Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)), Office of the Assistant Secretary of the Army for Civil Works (ASA(CW)), and U.S. Army Engineer Research and Development Center (ERDC). Within the Air Force, climate change is currently being addressed within the Office of the Assistant Secretary of the Air Force (Installations, Environment, and Logistics; SAF/IE). Within SAF/IE, the Deputy Assistant Secretary of the Air Force (Environment, Safety, and Occupational Health; SAF/IEE) is leading climate change-related initiatives. With the exception of ASA(ALT), each of the preceding organizations are interested in and should receive updates on opportunities to participate in regional assessment activities associated with the National Climate Assessment.

Both the Army and USACE are currently investing in research related to assessing the impacts of climate change and their management. The ASA(ALT) supports environmental research related to the management of technology development and Army operations, which includes

consideration of climate change impacts relevant to Army missions. The U.S. Army ERDC holds the lead role for conducting environmental research supporting both the Army's military and civil works missions, including climate change. As such, ERDC is currently conducting research to expand the Army's and USACE's capabilities to assess and manage risks related to climate change and variability. The USACE Institute for Water Resources is supporting the ASA(CW) through the development of policy and guidance for using existing science on coastal and inland hydrology, sea level change, flood frequency analysis, reservoir sedimentation, and droughts and other climate related topics. See Appendix E for a description of specific R&D activities underway within the Army.

Army and Air Force needs/requirements for climate change information relate to developing relevant *process* information, *analytics* for informing assessments and decision making, and reliable approaches for projecting *future conditions*. Requirements for *process* information relate to the need to: (1) use physical lines-of-evidence that can be measured currently to improve the modeling of climate processes at the regional scale, (2) reduce the uncertainty associated with the relationship between greenhouse gas (GHG) emissions and future consequences, and (3) understand the impacts of climate variables on the performance of DoD systems (e.g., ships, aircraft, sensors, etc.). The needs regarding *analytics* supporting assessments and decision making concern: (1) methods for characterizing and quantifying the implications of uncertainty in modeling and prediction for decision making, (2) improving methods for downscaling information and model predictions to scales that are relevant for the decisions under consideration, and (3) tools that support the development and evaluation of robust adaptive risk management strategies and plans. The need to improve capabilities for reliable prediction of *future conditions* under the influence of climate relate to: (1) predicting future energy and water conditions (including water quality, quantity, and demand) in relation to installations and future operational environments and (2) identifying environmental tipping points relevant to global and regional security and to managing built and natural infrastructure at installations.

The Army and Air Force expect to use climate change information in the following ways:

- Increasing the situational awareness of senior leadership on climate change phenomena and potential Service vulnerabilities and global risks at the strategic level.
- Risk assessment and identification of management actions that can be taken to reduce risks to the portfolio of Service assets, infrastructure, and missions at the full range of scales: globally, regionally, and locally.
- Technology transfer of tools and data to end users within operational organizations and at installations to support the development of local strategies and plans to address the projected consequences of climate change, including adverse effects caused by extreme events.

Service Breakout: Navy—The Navy's Task Force Climate Change (TFCC) is the principal Navy organization responsible for developing policy, requirements, and identifying Navy research requirements regarding climate change science, mitigation, and adaptation. All Navy components have representatives on TFCC who identify their organization's needs and questions regarding climate change science and research. These needs exist on spatial scales from sub-regional to global and on operational scales from tactical to strategic. As a result, a wide range of needs exist, including the development and implementation of mission/ operational/campaign

plans, infrastructure/facilities plans, education and outreach, policy development, development of Naval platforms, weapons and sensors, and the investments associated with these efforts.

Improvements are needed in the climate science and climate information necessary for addressing these Navy requirements, including: (1) developing models with higher temporal and spatial resolution; (2) developing a range of model types (e.g., statistical, dynamical, statistical-dynamical, multi-model); (3) improving the physics in physical models of sea ice, ice sheets, the atmosphere, the ocean, permafrost, and coastal zones; (4) reducing and quantifying the uncertainties of these physical models; (5) providing probabilistic output from climate models and in climate assessments; (6) improving understanding of abrupt climate change scenarios and likelihood; (7) improving modeling of geoengineering deployment and associated global system response; and (8) addressing the wide variety of adaptation science interest areas for the Navy, such as improving surface ship/system operational performance in cold regions and adapting coastal installations to sea level rise.

The Navy has several ongoing and planned activities related to climate change vulnerability and impact assessment, adaptation science, mitigation, and climate modeling. Organizations sponsoring or contributing to this work include the Office of Naval Research (ONR), the Naval Research Lab (NRL), the U.S. Naval Academy (USNA), the Naval Postgraduate School (NPS), the Naval War College (NWC), the Naval Facilities Engineering Service Center (NAVFAC ESC), TFCC/Oceanographer of the Navy, and the OSD's Strategic Environmental Research and Development Program (SERDP).

Although current Navy research efforts address these needs to varying degrees, new research is needed in: data access, management, and fusion; decision support; risk and uncertainty quantification; adaptation science; applications of operations analysis to climate change impacts/scenarios; and effective visual representation of climate data and predictions.

The greatest impediments to progress in supporting Navy climate change needs are the lack of availability of resources, educated personnel, and perception of the importance of climate change impacts on national security. In addition, it is important to define the scope of climate change and climate variability for Navy research and applications. Some important elements to consider when defining this scope are temporal and spatial scales of variability, valid periods for prediction, rate of change (e.g., abrupt climate change), high priority regions, spatial and temporal interactions within the climate system (e.g., teleconnections), and geoengineering.

2.2.2 Day 2

Coastal Environments—Increased knowledge is required of how climate change effects will transform coastal hazards and system drivers. In addition, understanding vulnerabilities and risks is needed for installation management and for natural systems and training under climate change drivers and hazards. Finally, knowledge also is needed on civil works infrastructure conditions and associated performance that installations depend on that also may be impacted by climate change.

Improvements are needed in model coupling for computational efficiency and representation of non-linear/dynamic feedback of climate change, scenario-driver influences on quantification of solutions. Techniques for characterization of uncertainties that propagate through the assessment

process are required for further development. The importance of using iterative approaches at different scales for alternative solution development and refinement must be emphasized and enhanced. Inventory of new climate change knowledge development (e.g., seasonal-scale variations in forcing) is required, beyond linking existing knowledge for executing vulnerability and risk assessments to support the ability to examine adaptations. The capability to work at multiple scales with existing methods/models and evolving them and the underpinning science are enablers that should be pursued. Significant improvements are needed in ecological modeling with guidance on how to sustainably assist natural processes in coastal marshes that can enable such marshes to keep up with sea level change. Identification is required on the tipping points in installation mission impairment that result in going from minor to catastrophic impacts, as well as for natural asset functionality.

Improved capabilities of earth systems instrumentation and greater span of deployments for data collection are critical to enabling quantitative assessments. Increasing the amount of computing power available to DoD scientists would be very supportive for achieving enhanced model resolution and run cycle times. Methodological approaches to explore the effects of non-linear feedbacks of systems and process models on risk assessment are required.

***Cold Region Environments*—**This breakout session explored the science and technology requirements for DoD in cold region environments and how to best transition such science and technology to the operational level and into programs of record. The most critical gaps regarding assessing and responding to risks for natural and built infrastructure in cold region environments include the lack of skillful predictive capability, incomplete understanding of the physical processes, the lack of skillful downscaling processes, and inadequate data sets. The physical phenomena that are most important but least understood include currents, sea ice, storm frequency and intensity, bathymetry, shoreline and geoid characterization, and permafrost.

To best transition science and technology to the operational level and into programs of record, existing programs designed for this purpose should be used. Examples of general DoD/Navy processes include OSD's Joint Capability Technology Demonstration (JCTD) process, the Navy Trident Warrior (TW) events for Fleet experimentation, and use of Joint Urgent Operational Needs Statements (JUONS) by the Combatant Commanders. Examples specific to environmental observation and prediction include the Naval Oceanography Enterprise's Rapid Transition Program (RTP), the Administrative Modeling and Oversight Panel (AMOP), the Naval Oceanographic Partnership Program (NOPP), and the Oceanographic and Atmospheric Master Library (OAML). Other mechanisms include efforts led by OSD's SERDP, USACE's Cold Regions Research and Engineering Laboratory (CRREL), the Navy's ONR and NRL, National Ocean Council (NOC), Unified Facilities Criteria (UFC) process, Defense Science Board (DSB), Naval Studies Board (NSB), State Department's Arctic Policy Group (APG), Center for Naval Analyses (CNA), and National Research Council (NRC). All of these organizations have conducted studies that have informed DoD programs of record on cold region science and technology requirements.

Inland and Arid Region Environments—Inland regions of the US, particularly those in the arid Southwest, are projected to experience acute responses to climate change in the next century. As evidenced by recent trends, the Southwest is warming more rapidly than many other regions of the nation. The warming has led to declines in spring snowpack and Colorado River flows. Increases in summertime temperatures will exacerbate urban heat island effects and alter the

hydrologic cycle. When combined, these threats foretell serious water supply crises in the decades to come. These trends are projected to continue or even accelerate under the higher end emission scenarios. Key concerns for the area include:

- increasingly scarce water supplies leading to conflicts between competing users;
- increasing temperature, droughts, and wildfires transforming the landscape;
- shifts in biodiversity and species composition (i.e., loss of indigenous species unable to adapt to the new setting or unable to adapt quickly and invasive species encroachment); and
- changes in timing and frequency of flooding.

For the military these changes can be considered a significant challenge to military readiness. In order for inland military leaders to adaptively manage their installations and assure mission performance into the future, critical scientific gaps in our understanding and knowledge of climate change and ecosystem response must be addressed. In the absence of policy and guidance, and lacking a cohesive understanding of natural ecosystem response to climate change, threats to infrastructure and weapons systems overshadow an installation manager's abilities to operate adaptively. Risk-based strategies and tools that help installation managers visualize ecosystem response to a variety of "What-if" scenarios are desperately needed to tactically and strategically respond.

Numerous scientific, engineering, and technological gaps must be addressed to inform decisions within this risk-informed decision making framework. Developing ecosystem response models that can characterize or capture the variability of these inland systems (given uncertain inputs from the climate models) is required. Infrastructure response models also are needed. Hydrologic modeling that indicates the frequency and magnitude of expected flooding, as well as 3-D groundwater modeling, is needed to characterize the threat to current military operations. Many of these technologies (models and decision support systems) exist, but have never been applied to the climate change problem. Other tools/models will need to be devised to address the unique challenges of adaptive management in the face of an uncertain future. Flexibility will be the key to developing useful tools to meet the challenge of dynamic climate change.

But first, installation managers need science-informed, defensible policies and guidance, tailored specifically to their 'decision-space' with directions on how to incorporate climate change and environmental response into decision making at multiple decision-making levels. These frameworks must be flexible/pliable so that the design criteria and specifications can be adapted as more information becomes available in the future. Thus, new guidance should tie to Master Plans and other similar documents and incorporate the following details:

- accepted levels of confidence and degrees of acceptable uncertainty;
- planning horizons;
- identification of credible emission scenarios to use and their sources that drive the climate models to generate anticipated "x, y, & z" environmental responses;
- identification of what the end-user or installation manager should consider (i.e., precipitation, temperature, etc.);
- contractual qualifications/capabilities; and
- incorporation of monitoring and iteration (adaptive management).

2.2.3 Day 3

***Vulnerability and Impact Assessments*—**Scientifically underpinned and strategically orchestrated modeling of changes in climate that potentially impact DoD installations must clearly describe how and under what scenarios DoD installations are vulnerable and could be adversely impacted by climate change. Tools that elicit value-laden responses of decision makers, based on this information, are needed to distinguish impacts on a relative basis and to rank negative and positive impacts to mission functions and supporting assets/capabilities for individual installations. These tools should employ indicators for describing system performance at successively higher levels in a framework that is able to cut across installation and command missions by type and by region on a geographic basis. Outputs should elevate the most certain and urgent potential losses and opportunities to sustaining performance of mission-critical infrastructure/training settings that are most effectively, efficiently, and expediently addressed via risk reduction and adaptation. Understanding is also needed on where to strategically focus investigative resources in successive tiers/iterations of vulnerability assessment, following the general approach described above, to scope where impact assessment is required within installation systems to sustain missions. Finally, identification of critical gaps in knowledge and understanding is an output requirement on climate science relevant to supporting future, continued vulnerability assessment.

Comprehensive impact assessment, as it relates to climate change variability and extremes, requires the ability to describe systems-scale performance in a probabilistic manner for objectives of interest from the present time into the long term, considering plausible future scenarios about key drivers with remaining uncertainties in scientific understanding. As a result, sufficient scientific understanding is needed to model the following in support of quantitative impact assessment at installations:

- projected changes in climate variability and extremes for the timeframes of concern at sites considered;
- characterized climate changes to the system considering current/planned practices;
- predicted changes in system forcings attributable to projected changes in climate; and
- definition of boundary conditions under a changing climate regarding interaction with external systems in which the installation is dependent.

An inventory of science, models, and tools that are available with explanation of their strengths and weakness is needed by the impact assessment community to support this work.

Policy and technical guidance should include those factors that will aide decision makers in advancing studies for identifying and acting upon the potential for large-scale, frequent, and long-duration likelihoods of loss to installation mission performance, as well as strategic opportunities for exploitation in further advancing missions. These include evolving national and international governance, identifying and articulating policy goals and objectives and how those translate from the strategic down to the tactical level, describing the types of policy decisions that need to be made and on what timelines, and providing the means for mission managers to effectively engage researchers in a role of technical support.

For research activities to be highly relevant and richly successful in addressing climate change for installation sustainability, they are best integrated systematically into the installation

operations for deep, continuous engagement of their community of practice. This would sufficiently engage end-users for practically developing and implementing vulnerability and impact assessments that work to achieve aims.

***Adaptation and Mitigation Science*—**Given the uncertainties of changing climatic conditions, and the potential vulnerabilities of Defense missions and assets to these changes, a key capability needed by Defense decision makers is a framework that provides relevant new condition data that is linked to Defense missions and assets. This framework may include many elements: such as structured human interactions, database updates and automated analysis, and visualizations and consequence analysis. It also should be relevant at multiple scales, as changing conditions need to be viewed and understood in multiple timeframes and against various short- and long-term response scenarios.

Natural systems that may be impacted sooner than later or to a greater extent include: shorelines, coastal fringe systems, groundwater and surface hydrology, sea ice, coastal erosion, ice sheets, and arctic land surfaces (tundra, permafrost, and methane release issues). Issues of concern include the stability of these systems in changing climatic conditions, threats to protected species under changing conditions, and changes in ecosystem dynamics, especially those changes that impact mission activities. Dialogue is needed with regulatory agencies responsible for various natural systems that might be impacted: such as for wetlands, endangered species, and protected marine ecosystems and species. In addition, the rapid implementation of renewable energy technologies, in part to reduce dependencies on fossil-based fuels, is having ecological impacts that need to be better understood.

For new facilities (and infrastructure) and for existing facilities that are being upgraded, changing climatic conditions are anticipated during their design life. Current engineering parameters, however, do not include any such considerations. As a result, a pathway is needed to develop an acceptable approach to update these engineering design parameters. For the most part, the guiding principles for smart planning increase climate resilience in facilities and infrastructure, and they should be applied at both the facility and the campus level. In addition, planning should incorporate regional and local data relevant to changing conditions: climate, land use, population, and other change factors. Facility research should seek to build climate resilience into future construction materials.

Because adaptation requires a strong linkage between data, analysis, and operational changes, R&D activities need to be closely integrated with operational activities. This can be accomplished by various bridging strategies, such as reach-back, staff exchanges, cross-teams (field operations, managers and technical teams) and social media that link stakeholders in collaborations on data analysis and the implications for operational adjustments. In addition, science and technology outcomes need to be tailored to fit into operational processes, by sharing the plan documents, spreadsheets, maps, and visuals used to make the operational decisions with the R&D capability developers and targeting their outcomes to more directly link to these operational decisions.

Climate change occurs over a long time line, so every update and iteration of a plan is an opportunity to insert new data, new analysis, and planned observations or adaptations. This needs to be done across all plans impacted by changing climatic conditions (master planning, strategic planning, sustainability planning, natural and cultural resource management planning,

training planning, infrastructure assessment, etc) and these plans all need to interact in a dynamic fashion, in which updates to one plan are linked and coordinated, as they are made, across all other impacted plans. To accomplish this, policy and guidance documents need to be updated, to routinely require such adjustments, and to incorporate capabilities to establish useful feedback across plans that help guide users through multiple planning adjustments.

The specific policy and technical guidance needed by Defense organizations will vary over time, and the most logical way to ensure that the appropriate strategies, models, tools, and technical input are available to Defense organizations is to establish, in support of a Defense working group on climate change adaptation, necessary technical participation through technical support committees or otherwise. These committees need to have strong linkages with the USGCRP and the NCA, as well as with other agencies that are gathering, analyzing, and providing technical data on changing climatic conditions. Members of technical committees should include key R&D organizations across the Department of Defense that are engaged in adaptation-related topics.

3 Workshop Synthesis: Major Findings and Emergent Themes

The unique nature of this workshop—the bringing together of those individuals involved with climate change policy development from the Office of Secretary of Defense (OSD), military Services, and US Army Corps of Engineers (USACE) Civil Works program, the Department and Services' research and development (R&D) community, and external federal partners in an initial dialogue—reaffirmed that climate change matters to the Department of Defense (DoD) and an effective response will require close and continuous integration between the DoD policy and R&D communities, as well as effective partnering with other federal agencies via a whole-of-government approach. The various workshop plenary and breakout sessions, supplemented by the policy panel and general discussions that occurred throughout the workshop, highlighted a number of major findings and emergent themes that are synthesized and summarized in this section. To best develop and portray this synthesis, the information that follows is subdivided into thematic categories rather than by type of session as in Section 2.

3.1 The Context for a Response to Climate Change in the Department of Defense

The current policy drivers for DoD action with respect to climate change are the February 2010 Quadrennial Defense Review and the March 2011 Council on Environmental Quality (CEQ)-issued Federal Agency Climate Change Adaptation Planning Instructions. In addition, DoD articulated its broad strategy for evaluating climate-change risks and vulnerabilities in its initial Strategic Sustainability Performance Plan (SSPP), dated June 2010, in response to Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance.[1] The CEQ instructions require DoD to submit a Department-level analysis of key vulnerabilities to climate change by March 2012, as well as a Climate Adaptation Plan by June 2012 concurrent with DoD's updated SSPP.

Beyond the preceding, workshop participants noted that specific step-down policy and guidance regarding climate change vulnerability, impact, or risk assessment/management and adaptation generally has yet to be issued at the Department level. This includes but is not limited to defining bounding assumptions and their temporal and spatial scales, such as sea level change, climate change, and extreme event scenarios, to guide vulnerability, impact, and risk assessments, as well as development of adaptation strategies and actions. One limited exception is the broad requirement imposed by DoD Instruction 4715.03, Natural Resources Conservation Program (dated February 14, 2011) that requires installation Integrated Natural Resources Management Plans (INRMP) to assess the impacts of climate change to natural resources and to take steps to ensure the long-term sustainability of those resources. But again specifics as to how to proceed are not provided.

As a result, the plenary sessions and policy panel discussion highlighted the need for and challenged the DoD R&D community to assist with providing technical support to the policy community that would meet their needs for determining:

[1] EO 13514 also included elements related to greenhouse gas reduction targets and energy efficiency and renewable energy goals that in combination constitute mitigation actions related to climate change. Policy aspects related to climate change mitigation were not the focus of the workshop except when adaptation and mitigation strategies are linked and strategies to reduce emissions may have unintended consequences that affect adaptive capacity, such as when considering forest restoration strategies to sequester more carbon that may reduce ecosystem resilience.

- which climate change and other types of scenarios to consider for planning and action and over what temporal and spatial scales;
- which infrastructure/assets, operational, and readiness considerations to focus on first and where;
- leading indicators of change to readiness, built infrastructure, and ecosystems and their implementation and use; and
- in what contexts to consider climate change.

The contexts under which climate change must be considered are many and complex. To provide adequate technical support, the R&D and policy communities must take into account the interconnections/interdependencies associated with climate change science, policy, geopolitics, and national security. For climate change science, interconnections exist between spatial scales (e.g., local, regional, global), temporal scales (e.g., intra-seasonal, annual, inter-annual, decadal, and longer), environmental domains (e.g., air, ocean, land, and space), and regions (e.g., tropics, mid-latitudes, and polar regions). For the relation of climate change to policy, geopolitics, and national security, interdependencies exist due to political, economic, and demographic factors, as well as local governance, scientific literacy, and media orientation factors. Finally, climate change occurs in the context of other anthropogenic stressors. Often, climate change will potentially exacerbate the effects of these other stressors, sometimes in non-linear ways. Adaptation to climate change often may be accomplished by increasing an asset or ecosystem's resilience to a non-climate stressor.

Besides defining the technical bounds of policy-relevant information related to climate change, the R&D community also has a responsibility with translating the implications of the current and planned science and technology needed by policy makers and the end-user (installation managers and operational units) so that they have actionable information. The uses of climate change information within DoD include three broad areas:

- Increasing the situational awareness of senior leadership on climate change phenomena, vulnerabilities, and risks, including at the global and strategic levels.
- Risk assessment and identification of management actions that can be taken to reduce risks to the portfolio of DoD missions, assets, and infrastructure at the full range of scales: globally, regionally, and locally.
- Technology transfer of tools and data to operational end users at installations to support the development of local strategies and plans to address the projected consequences of climate change, including adverse effects caused by extreme events.

3.2 Internal Capacity, External Partnerships, and Outreach

The Department possesses a range of science and engineering capabilities relevant to understanding and analyzing the vulnerabilities, threats, and risks that climate change poses to DoD missions, assets, and infrastructure. Future development and coordination of these capabilities, across OSD, the Services, and the USACE Civil Works program will enable DoD to capitalize on its corporate technical capacity and effectively leverage the technical capacity in other agencies and organizations.

In addition, research to support and inform DoD climate change assessment, adaptation, and mitigation efforts must leverage partnerships and the whole of government. In view of

increasing fiscal constraints within DoD, climate change research must be planned and conducted in coordination and collaboration with other efforts across the U.S. government and scientific/academic communities to avoid redundancy and to increase efficiency. For example, continuous engagement and coordination with the activities of the US Global Change Research Program, in particular with the associated National Climate Assessment (NCA) and adaptation science/planning efforts, is paramount. The recent emphasis on these activities has been to improve assessment methodologies, provide credible climate, environmental, and socioeconomic scenarios, and enhance climate information transfer to end users and policy makers. The Department should continue to remain engaged in these efforts and make sure its needs and concerns are addressed through the sustained assessment process that is now the focus of the NCA.

Finally, research to support and inform DoD climate change assessment, adaptation, and mitigation efforts must ensure linkages to education and outreach. The DoD relies on the support of the U.S. public for all of its endeavors. To ensure public support for DoD climate change-related research, and for implementing resultant adaptation and mitigation strategies, the DoD should conduct proactive strategic communication efforts, support associated education programs, and conduct targeted public outreach regarding the impact of climate change on national security, readiness, and stewardship requirements.

3.3 Blueprint for a DoD Climate Change Research Agenda

Research needed to support DoD's response to climate change involves both fundamental and applied science, as well as translation of that science into actionable information for policy makers and end-users. On a thematic basis, research and translation needs can be divided into climate system modeling, physical forcings and environmental process modeling, assessment and adaptation methodologies/strategies. The Department R&D community will not be the primary provider for all research needs, but will still serve a vital role in fulfilling DoD-specific research and translation needs. DoD sponsored research should be responsive to user-defined needs.

Climate (Earth) System Modeling—Research to support and inform DoD climate change-related efforts must address necessary improvements to the science regarding climate physics that operate over multiple spatial and temporal scales. In addition, geoengineering, and its use to alter the behavior of the climate system, is an emerging area of investigation that DoD should at least remain aware of its progress and implications. Science improvements required to inform DoD climate change decisions, whether undertaken by DoD or others, include: reducing and quantifying the uncertainties of earth system models—including, when appropriate, improving probabilistic output for climate models and resultant assessments; developing higher temporal and spatial resolution climate models; and improving model physics for a wide variety of phenomena (especially the contribution of ice sheet retreat/melt to sea level rise and the influence of abrupt climate change on Arctic ice retreat). In addition, understanding the appropriate use and non-use of statistical and dynamical (regional climate models) downscaling techniques is a vital component of climate change model research when attempting to right-size climate information for decision making purposes.

Physical Forcings and Environmental Process Models—Physical processes (i.e., forcing functions) that represent how earth systems respond to changes in weather and climate need to be considered at regional and local scales. Beyond local sea level change, storm surge, and inland

flooding during large precipitation events, consideration should be given to changes in physical process-based hazards including wind, sediment movement (erosion / sedimentation), and constituent releases, movements, fate, and effects. Natural systems respond to these forcings, and how they do so is important in understanding their adaptive capacity. As a result, continued improvements are needed in the representation of biotic and abiotic components of environmental process models that are relevant to DoD geophysical settings and ecosystems. In particular, research is needed to understand and attribute relevant ecosystem response endpoints related to climate change to on-the-ground effects that can be used to monitor sites, identify tipping points (critical thresholds), and/or asses impacts to mission critical capabilities and assets.

Assessment and Adaptation Methodologies/Strategies—Given the complexities involved in relating future climate to effects on DoD missions, assets, and infrastructure, new policies and analytical capabilities will be needed to support coherent assessments and adaptation strategies that minimize costs and risks to mission critical functions over time. This will require defining at the policy level the key decisions the military is contemplating at appropriate spatial and temporal scales, which will then enable scoping the technical assessments that are needed. In addition, technical guidance is required for distinguishing the types of assessments that are needed and appropriate—screening level versus detailed and vulnerability versus impact versus risk (see Appendix C for definitions)—and the data requirements and performance standards expected for each. Appropriate and scientifically credible climate change and other scenarios also must be defined to drive the assessments. Models and decision support systems should facilitate planners and managers to conduct "What-if" scenario analysis in a transparent, meaningful manner.

The preceding must be applicable to installations globally: that is, any guidance must account for the different biophysical settings, native ecosystems, and regional expressions of climate and physical forcings encountered by installations while maintaining appropriate levels of regional consistency in approach and assumptions. In brief, guidance should reflect systematic climate change risk reduction that is scale dependent and, as such, considers common assumptions that are applicable across large spatial scales while acknowledging the unique risk and management issues that may occur regionally/locally. Detailed impact assessments may be needed at installations characterized as highly vulnerable to climate change effects for identification of mission impairment tipping points and associated networked mission assets/capabilities.

Adaptation science is in its infancy. Existing knowledge on built and natural infrastructure responses to physical forcings provides a starting point, but new knowledge is needed to understand how natural and built infrastructure will respond to climate change and affect the adaptive capacity of infrastructure systems to maintain desired functions with and without intervention. A framework and supporting processes to stage adaptation must be devised to account for uncertainty in the climate projections and their effects, guard against excessive and unneeded costs, avoid maladaptive responses, and manage risks to ensure continued mission sustainability. Guidance on effective communication and technical transfer of information to installation management personnel will improve opportunities that new knowledge is employed in identifying potential adaptation strategies.

3.4 The Need for a Policy-R&D-End-User Dialogue

Policy and guidance have yet to be firmly established to support both tactical and strategic planning in the face of climate change. What the Department needs is a robust, scientifically defensible approach that transparently communicates risks to the end-user and helps policymakers develop guidance to promote mission sustainability in the face of climate change. Although R&D on built and natural infrastructure response to climate change has progressed in recent years, a coherent vision of installation and operational military vulnerabilities has not been compiled. In the absence of comprehensive and coherent policy and guidance, current OSD- and Service-led R&D initiatives have taken a no-regrets, but mostly uncoordinated, type approach to the problem rather than developing and adhering to a comprehensive, across the Department strategic approach. As a result, the current focus has been on critical areas of interest (sea level rise, permafrost melt, inland flooding, Pacific Islands, etc.) that are viewed by OSD or Service R&D programs as vulnerable in the near-term or for which long-term infrastructure planning decisions are involved.

Policy awareness is emerging, but its growth and maturity to meet both strategic and tactical DoD needs would be best served by an ongoing and interactive dialogue between the policy, end-user, and R&D communities. Adaptive, risk-based decision frameworks that assess vulnerabilities, impacts, and risks, as appropriate, are needed and should be developed jointly and iteratively among these communities to incorporate climate change into tactical and strategic planning activities, with prioritization based on the types of decisions to be made and their spatial and temporal aspects. Policy and guidance also should be established to effectively incorporate adaptive management principles into all military planning and operations in the face of climate change. Finally, policy and guidance will need to be clear, flexible, iterative, and adaptive themselves to ensure appropriate consistency and currency while providing the Services the opportunity to decide how to best implement the requirements in the most efficient and effective manner.

Climate change adaptation involves responses to observed and projected trends that require observations and analyses of data relevant to this trend, as well as projections of the future range of trend possibilities. These observations and trend analyses have been (and are being) conducted by the R&D community; however, observations and trend analyses are often only available over relatively short timeframes, when observations are needed to track and analyze trends over long timeframes. Moreover, usable science is needed to link information on changing conditions to Defense assets and operations by identifying vulnerabilities, assessing the potential impacts, and crafting strategies to adapt to these changes. This requires very close linkages and frequent interactions between the R&D community and those who manage and maintain Defense assets and plan and conduct Defense missions. Some keys to accomplishing the preceding are:

- Structure R&D activities and experts to be well connected and frequently interacting through a variety of means (reach-back, cross-over panels, cross-over assignments, technical advisory panels for adaptation committees, clear integration of new information, linkages to impacts and actions in plans and budget requests, etc)
- Focus first on built and natural systems with relatively near-term vulnerabilities.
- Integrate resilience into adaptation strategies to enhance the sustainability of assets and missions under a range of potential future conditions.

3.5 Notes on Implementation

In addition to the dialogue mentioned in the previous section, workshop participants identified a number of specific suggestions for implementation of climate change-related policies and guidance. These can be summarized as follows:

- Develop a process and guidance for climate change-based installation operations research studies, pilot projects, documentation of lessons learned/best practices, and technical assessment product transition to the field (communication, training, support, guidance, resources, and program development).
- Specify in the Program Objective Memorandum (POM) the integration of climate change studies into current (established) policies and practices (e.g., Master Plans, INRMPs, Environmental Management Systems, etc.). Plan to review, identify, and recommend changes to commonly used planning and policy documents to accommodate climate change-related concerns and issues.
- Coordinate incorporation of the science and practices for addressing climate change issues into recognized accreditations (e.g., National Institute of Standards and Technology, etc.).
- Consider that of the many advantages of climate change research to the DoD, one of the most important is in providing observational and predictive information concerning relevant phenomena, at relevant temporal and spatial scales, that is useful for developing cost-benefit, risk, and return-on-investment assessments for planning operations and making resourcing decisions.

4 WORKSHOP RECOMMENDATIONS

The workshop plenary and breakout sessions, as well as the numerous discussions that these sessions generated, resulted in many ideas, findings, and recommendations. Various components of this report attempted to capture and summarize the preceding. Chapter 3 attempted a synthesis of the sessions and discussions to arrive at major findings and key emergent themes. Here the focus is on the main workshop recommendations using a brief summary format.

4.1 Visioning Future Workshops

The Department, inclusive of the military Services and U.S. Army Corps of Engineers, Civil Works program, has an ongoing need to assess the state of the science, practice, and policy needs relative to understanding the mission challenges raised by climate change and the framing of appropriate responses to such challenges, including their spatial and temporal aspects. Workshops (both in-person and virtual) can be a primary and helpful tool to accomplish such assessments.

Workshops may attempt to leverage the activities of the other federal agencies (see section 4.5); however, internal workshops will be necessary to ensure incorporation of current science into Department of Defense (DoD) processes and policy and to support the development and maintenance of required DoD capabilities. Conveners of future workshops may include coordinated efforts among those entities that planned and executed the current workshop and other DoD components.

Workshops should be of alternate formats and technical scope depending on the need at the time and held in some form no less frequently than once every two years. Organizers should be cognizant of costs involved and look to leverage other already planned meetings or use virtual technologies to convene participants when feasible. Workshop formats may include:

- Mostly just the DoD research and development (R&D) community. These workshops would explore DoD-relevant science gaps and to coordinate future internal research efforts to address these gaps. These types of workshops may benefit from periodically including other federal agency and academic scientists to broaden the discussion and expertise.
- The DoD R&D community and installation end users. These workshops can serve to better understand the state of the practice and user driven research needs. These workshops also can include identifying demonstration and transition issues to improve the utility of scientific information to the end-user community.
- The DoD R&D and policy communities (similar to the current workshop). These workshops would help these communities maintain an ongoing dialogue to ensure DoD-sponsored and conducted science is policy relevant and could assist policy makers in understanding the state of the science as one input to their policy decisions.
- Combinations of the preceding, though the planning and execution for such workshops would be more difficult than any of the others.

4.2 Establishing an Ongoing Dialogue

The DoD R&D and policy communities should establish those mechanisms necessary to maintain an ongoing dialogue.

Climate change and climate variability, including extreme events, add new challenges to DoD's policy and decision making. Besides its direct effects, climate change often exacerbates other environmental stressors, but more importantly it extends the temporal scale of decision making beyond what is traditional and adds increased amounts of uncertainty to projected futures and the effects of any decisions taken in response. Still, an action not taken because of uncertainty is itself a decision that ultimately has consequences. Because of DoD's operational and readiness missions, the enormity and complexity of its infrastructure, and the spatial distribution of its assets and operations, no other agency is faced with the breadth and complexity of decision making that climate change poses for DoD.

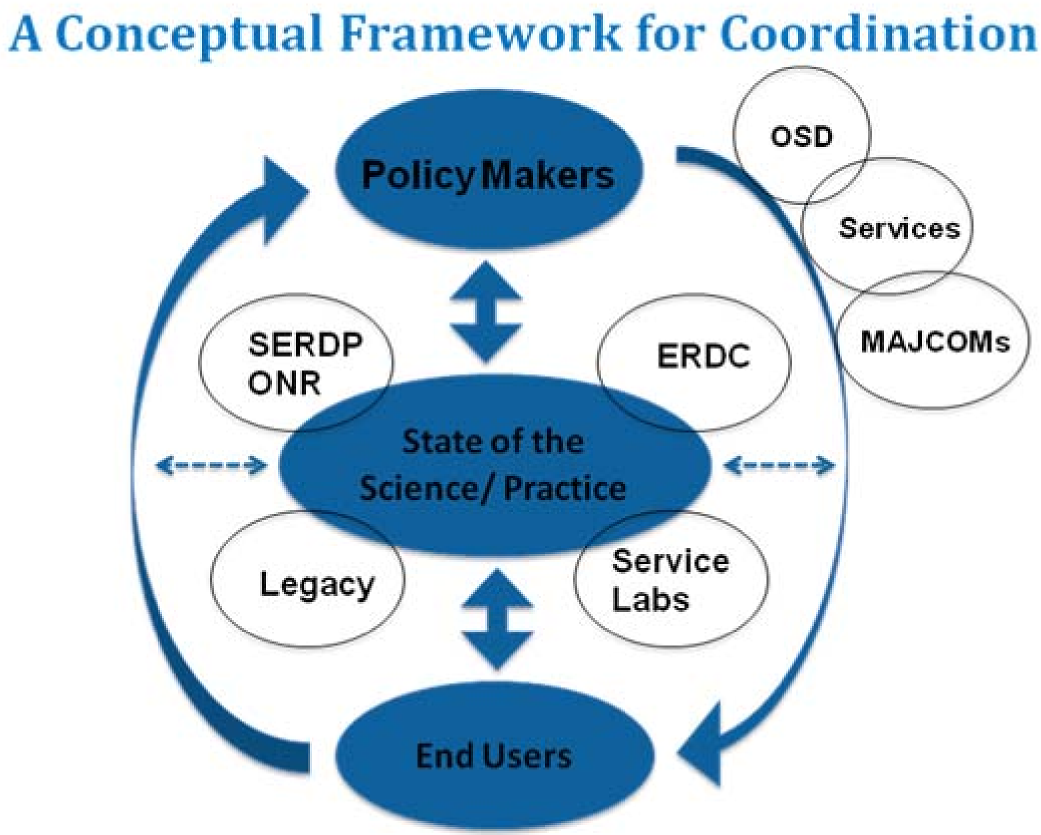
For these types of situations, a new paradigm of science-policy interaction and organizational cultural change is needed. Although research that is unaligned with policy (i.e., not immediately relevant) may at times provide an insurance against research and policy being too myopic, aligning research and policy development at the early stages can provide scientific grounding for decision making. As policy matures, alignment ensures that research is relevant and has direct utility for the identified needs of the Department. When the policy issues are clear, research can then best be directed to understanding the relevant impacts of climate change on DoD and crafting effective and efficient responses. Research also can be used to identify new problems and vulnerabilities that have yet to be considered or incorporated into policy, which provides one mechanism for minimizing surprises.

The figure below—modified from one shown during a plenary session—shows in graphic form a conceptual framework for coordination between the R&D, end-user, and policy communities. Decisions/policies and actions are made and implemented at different levels of the DoD/Service hierarchy. What they share in common in the framework is the two-way and necessarily iterative nature of the communication links. Both of these aspects are critical. The complexity of the science and policy challenges requires mutual, adaptive learning among the communities. It also may require learning of a unique nature: that is, by incorporating social and organizational research that can assist an organization the size and complexity of DoD to better integrate emerging knowledge into its decision processes and transcend traditional stovepipes and current ways of thinking and acting, which themselves may be maladaptive under future climate change and climate variability.

4.3 Establishing a DoD Climate Change Science Technical Workgroup

To support DoD's Climate Change Adaptation Planning Task Force—whose establishment by OSD(I&E) is underway—DoD should consider establishing a DoD Climate Change Science Technical Workgroup that can interact directly with the Task Force on matters of climate change science-policy intersection. At least one member of the Workgroup should be a member of the Task Force and serve a liaison function.

This recommendation is an important, though not the only, step towards establishing the ongoing dialogue discussed in section 4.2 above. The initial focus of the Task Force is on responding to



the Federal Agency Climate Change Adaptation Planning Implementing Instructions issued by the Council on Environmental Quality (CEQ) in March 2011 that mandated each agency submit a Climate Adaptation Plan by June 2012. In addition, an intermediate step to this plan is a Department-level analysis of key vulnerabilities to climate change due to CEQ as a final analysis during March 2012. A Technical Workgroup can be of assistance to the Task Force in developing the DoD response.

The role, however, of the Task Force and the Workgroup and the interactions between these entities should not end with the response to CEQ. Their formation and sustenance provides an opportunity for DoD to craft and implement a larger and more in-depth vision for how it will respond and adapt to climate change in a manner that meets its needs and the complexity and breadth associated with its missions and assets at appropriate spatial and temporal scales.

The DoD Climate Change Science Technical Workgroup should be composed of senior managers/staff from the appropriate DoD/Service environmental and engineering R&D funding organizations, laboratories, and academic centers. The U.S. Army Corps of Engineers, Civil Works program should have standing membership on the Workgroup, whereas membership by other federal agencies can be considered on a case by case basis when appropriate expertise may be needed.

4.4 Articulating a Path Forward: General Recommendations/Precautions

The DoD R&D community must provide defensible science, models, and tools to support DoD and the Services' needs regarding climate change and extreme event forecasting ability to meet operational needs, vulnerability and impacts assessments based on robust climate change scenarios, adaptation science, and mitigation.

In serving a role as an "honest broker" in technical matters related to climate change, the DoD R&D community can provide the technical voice regarding the "right" pace, spatial scale, and assumptions (e.g., change scenarios) for those vulnerability and impact assessments, whether they be high-level screening assessments or detailed and complicated assessments, that DoD and the Services choose to pursue. In addition, it can provide a similar function with respect to adaptation and mitigation strategies. The end result would be to assist DoD and the Services in avoiding unnecessary costs, inconsistent assumptions, and potentially maladaptive responses.

The preceding requires close coordination between the R&D and policy communities. Both communities must understand the needs of the user community. In addition, the R&D community plays a central role in translating what the science means to the policy makers and how it can be implemented by the user community. The DoD R&D community must understand its role with respect to policy development and implementation and be an available resource to the policy and end-user communities.

Finally, the R&D community can assist the policy community with identifying appropriate mechanisms for implementation of technical guidance. This could occur, for example, via integration of climate change studies into current (established) policies and practices (e.g., Master Plans, Integrated Natural Resources Management Plans, Environmental Management Systems, etc.). The R&D community can assist with reviewing, identifying, and recommending changes to commonly used planning and policy documents to accommodate climate change-related concerns and issues.

4.5 Forging External Partnerships

We do not have the resources to respond to the challenge of climate change alone. DoD should establish new and strengthen existing relationships with the federal R&D community, in part by participating in inter-agency research coordination efforts, to leverage resources, avoid redundancy, and highlight the Department's research needs.

The Department has been a long-standing member of the U.S. Global Change Research Program and has been an active participant in the 2013 National Climate Assessment and the sustained assessment process. In addition, DoD is playing an active role in the federal adaptation planning effort. These efforts have broadened DoD's interaction with the federal climate change R&D community and must continue as the shift in emphasis goes from a focus on improving the climate models to making actionable information regarding climate change and climate variability accessible to those that need to make assessment, adaptation, and mitigation decisions regarding climate change. The workshop was enriched by the participation of federal partners and such interactions should continue in the future. As centers for climate change information develop and mature, integration with the rest of the federal community will gain in importance

while at the same time DoD must ensure its own unique needs are met through a sustained DoD R&D enterprise.

APPENDIX A1 WORKSHOP CHARGE

Coordination Workshop on Climate Change-Related Research and Development Activities within the Department of Defense

July 19−21, 2011

Aurora, CO

Workshop Charge Statement

Background: The February 2010 Quadrennial Defense Review (QDR) recognized that climate change will affect the Department of Defense (DoD) in two broad ways:

- First, climate change will shape the operating environment, roles, and missions that DoD undertakes.
- Second, the DoD will need to adjust to the impacts of climate change on its facilities and military capabilities.

The QDR also recognized that DoD must develop policies and plans to manage the effects of climate change on its operating environment, missions, and facilities. In addition, the QDR committed DoD to completing a comprehensive assessment of all of its [permanent] installations to assess the potential impacts of climate change on its missions and to adapt as required. And finally, the QDR highlighted the need for DoD to regularly reevaluate climate change risks and opportunities and to work collaboratively with outside partners to meet the challenges posed by climate change.

Given the above, the focus of the workshop is first on establishing a DoD network of funding entities and research centers and laboratories involved in climate change-related research and demonstration and second on identifying the role that DoD's research and development (R&D) community can serve to (1) assist DoD policy makers by providing the technical foundation for advancing new policies related to climate change and (2) provide DoD resource, infrastructure, and operational managers the needed science information, models, and tools needed to implement the effects of policy "on the ground."

Objective: The DoD Research and Development (R&D) community must determine how its limited research and demonstration funds can best be invested to improve DoD's ability to respond to the challenges of climate change, both in the near- and long-terms. To strategically guide future investments and facilitate long-term cooperation and coordination among workshop participants, this workshop will:

(1) initiate establishing a communication network among the DoD R&D community working on climate change-related issues;
(2) identify the current range of research and demonstration activities related to climate change that the DoD R&D community is actively pursuing or planning;
(3) conduct a preliminary assessment of the current state of DoD policy and implementation needs relative to climate change and how well current activities align;

(4) identify the relationship of the DoD R&D community to the US Global Change Research Program and other Federal efforts to provide climate change-related information and identify opportunities for enhance coordination;
(5) develop an initial roadmap for a path forward to guide future investments across the DoD R&D community;

Approach: The workshop, to be held at the Embassy Suites Hotel in Aurora, CO, July 19−21, 2011, will be an invitation-only forum of about 50−70 participants. Invitees to the workshop will include senior program managers and researchers from the DoD R&D community, invited non-DoD Federal guests, and senior policy staff from the Services, Corps of Engineers, and the Office of the Secretary of Defense, Installations and Environment OSD (I&E). Elements of the workshop will include plenary presentations and two to four breakout sessions on relevant topics.

Product: The workshop activities, deliberations, and findings will be summarized in a workshop report that will serve as an initial guide to ongoing and currently planned investments in climate change-related research and demonstration. In addition, an initial wiring diagram that depicts the emerging DoD climate change-related R&D community will be prepared.

Sponsors: This event is sponsored by the Office of Naval Research, which is providing all of the logistical support. The Strategic Environmental Research and Development Program is providing technical assistance.

APPENDIX A2 WORKSHOP AGENDA

Department of Defense Climate Change Coordination Workshop			
Tuesday July 19, 2011			
0800-0830	**Workshop Registration & Coffee**		
0830-0845	Workshop Opening & Welcome	Dr. Charles L. Vincent	Navy: ONR
		Dr. John Hall	OSD: SERDP/ESTCP
0845-0930	Why this workshop?	Vincent/Hall	ONR/SERDP
0930-1015	USGCRP/NCA Overview	Dr. Tom Armstrong	USGCRP, Director
1015-1045	**Break**		
1045-1115	Perspective OSD: Installations and Environment	Ms. Maureen Sullivan	OSD: I&E, Environmental Management
1115-1145	Perspective OSD: Training Readiness and Strategy	Mr. Frank DiGiovanni	OSD: TRS
1145-1215	Perspective USACE Civil Works	Mr. James Dalton	USACE: Chief of Engineering and Construction
1215-1315	**LUNCH**		
1315-1330	Break Out Session 1 Charge	Vincent/Hall	ONR/SERDP
1330-1545	Service Coordination Break Out Sessions: Compile Current/Planned/Needed R&D	Army/Air Force Navy	Dr. Todd Bridges, USCAE CAPT Tim Gallaudet, Navy
1545-1615	**Break / Session Chairs Prepare Breakout Group Report Outs**		
1615-1715	Report Outs by Service	TBD	Session Chairs
1715-1745	Open Discussion/Next Day Overview	Vincent/Hall	ONR/SERDP
1745	**Adjourn for the Day**		
1800	**Reception-Light hors d'oeuvres / Posters**		

Department of Defense Climate Change Coordination Workshop			
Wednesday July 20, 2011			
0800-0830	**Coffee**		
0830-0845	Policy & End User Needs: Intro	Vincent/Hall	ONR/SERDP
0845-0915	Perspective Navy: Task Force Climate Change	CAPT. Gallaudet	Oceanographer of the Navy
0915-0945	Perspective Air Force: Environment, Safety, and Occupational Health	Dan Kowalczyk	Air Force ODAS: ES&OH
0945-1015	Perspective Army: Environment, Safety, and Occupational Health	Mr. Tom Mooney	ARMY ODAS: ES&OH
1015-1045	Panel Discussion (include OSD speakers from day before)	Vincent/Hall faciltate	N/A
1045-1115	**Break**		
1115-1200	Climate Services	Dr. Eileen Shea	NOAA
1200-1315	**Lunch**		
1315-1320	Breakout Session 2 Charge	Vincent/Hall	ONR/SERDP
1320-1545	Breakout Session 2 : Cross Cutting Themes 1	**Breakout Group**	**Session Chairs**
		A - Coastal Environments	Mr. Wiliam Curtis, USACE
		B - Cold Region Environments	CAPT Tim Gallaudet, Navy
		C - Inland & Arid Region Environments	Ms. Kelly Burks-Copes, USACE
1545-1615	**Break / Session Chairs Prepare Breakout Group Report Outs**		
1615-1715	Report Outs on Cross Cutting Themes 1	TBD	Session Chairs
1715-1745	Open Discussion / Next Day Overview	Vincent/Hall	ONR/SERDP
1745	**Adjourn for the Day**		

Department of Defense Climate Change Coordination Workshop			
Thursday July 21, 2011			
0800-0830	**Coffee**		
0830-0835	Breakout Session 3 Charge	Vincent/Hall	ONR/SERDP
0835-1045	Breakout Session 3 : Cross Cutting Themes 2	**Breakout Group**	**Session Chairs**
		A - Vulnerability and Impact Assessment	Dr. Edmond Russo, USCAE
		B - Adaptation and Mitigation Science	Mr. William Goran, USACE
		C - Climate Science	This session was eliminated
1045-1115	**Break / Session Chairs Prepare Breakout Group Report Outs**		
1115-1215	Report Outs on Cross Cutting Themes 2	TBD	Session Chairs
1215-1245	Next Steps and Workshop Wrap Up	Vincent/Hall	ONR/SERDP
1245-1400	**Lunch**		
1400-1730	Workshop Documentation (Planning Committee and Session Chairs)		
1730	**Adjourn**		

Appendix A3 Breakout Session Charges

Breakout Session 1:
Service Breakouts

Charge/Example Questions to Discuss

1) Who (person or office) in your Service is interested in and should receive updates on the US Global Change Research Program (USGCRP) or may want to present needs or questions to the DoD USGCRP representative so he can query USGCP relative to the federal investment in climate change science and its relevance to the DoD/military Services? (The goal is to develop the basis of a communication "wiring" diagram, so names, email, office symbol would be useful in the listing.)

2) The next National Climate Assessment is now underway with a target date of a 2013 report to Congress. Included may be updates to or new assessments at the regional scale. Who (person or office) in your Service is interested in and should receive updates on opportunities to participate in regional assessment activities? (The goal is to provide a list of interested offices/participants by region through the DoD Interagency National Climate Assessment Task Force representatives.)

3) What research or activities is your Service, either internally or though extramural funding, actively conducting or planning to conduct that are related to climate change vulnerability and impact assessment, adaptation science, mitigation, or climate modeling? (The goal would be a list of what is underway or planned, where/who, and the requirement being addressed.)

4) What do you see as the current requirements or demands for climate information from your Service that will drive the need for future research? (The goal is a list of future needs, research required, by whom.)

5) How do you envision your Service using climate information: are their new needs for research or information translation to support these efforts?

Services self-select breakout group Chairs. (Dr. Todd Bridges, USACE, chaired the Army/Air Force session and CAPT. Tim Gallaudet, Navy, chaired the Navy session.)

Breakout Session 2
Cross-Cutting Theme 1: Regional Research and Development Needs

Charge/Example Questions to Discuss

Overall charge: As climate change advances, DoD will be required to maintain readiness and operate in new and changing environments. This breakout session will examine several of these

environments, which are subject to rapid change or long-term infrastructure planning needs, to determine R&D needs specific to each.

Group A − Coastal Environments

Charge: Coastal environments will be one of the most sensitive to climate change as they are exposed to the effects of sea level rise, potentially enhanced storm activity, ecosystem shifts, and salt water intrusion into groundwater supplies. Many DoD locations are located in coastal environs that provide valuable operational, training, testing, and ecosystem services in strategic locations.

Relevant ***questions*** include:

1) What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure from local sea level rise, storm surge, and inland flooding during large precipitation events?

2) What technical needs are relevant to evaluating and distinguishing among alternative adaptation strategies for increased storm frequency and/or intensity for both built and natural infrastructure?

3) What scientific and technology advances are needed to develop reliable predictions concerning future changes in coastal ecosystems under the combined effects of climate and land use change and how those ecosystem changes will affect military infrastructure, readiness, and operations?

4) What policy and technical guidance is needed for determining which climate and sea level rise scenarios should be used and at what spatial scales to drive risk assessment and response in coastal environments?

Session Chair: Mr. William Curtis, USACE

Group B − Cold Region Environments

Charge: Changes in cold region environments may affect DoD readiness and operations. The Navy in particular identified the Arctic as its near-term climate change concern, including possible changes in mission and required capabilities. Continued access to and use of training lands by the Army is contingent on permafrost conditions, which are subject to degradation under a warming climate. A relatively broad understanding of research needs has been developed for this region but a gap in translating needed information into requirement.

Relevant ***questions*** include:

1) How can science and technology developments from the research community be best transitioned to the operational level and into programs of record?

1) What is the best mechanism to ensure operational planning documents and programs of record are informed on a regular basis by science and technology developments?

2) What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure in cold region environments, in particular as a result of thawing permafrost, poorly understood coastal erosion processes, and altered fire and hydrologic regimes?

3) What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive risk assessment and response in cold region environments?

Session Chair: CAPT Tim Gallaudet, Navy

Group C – Inland Regions, with a Focus on Arid Regions

Charge: Climate change is expected to produce increased warming and altered precipitation patterns in inland regions, especially in the arid Southwest US. Even if mean precipitation increases, rainfall variability and cycles of drought and extreme precipitation events will likely increase. The preceding changes will affect the nature of flooding events, the quantity and quality of water, energy usage patterns, fire regimes, and ecosystem shifts.

Relevant ***questions*** include:

1) What are the critical science gaps concerning climate change and land use impacts occurring within inland environments that are most relevant to military installations and their activities?

2) What science, engineering, or technology gaps should be addressed to advance our ability to inform decisions about the risks climate change poses to military infrastructure and training and testing capacity in inland regions?

3) What technology developments are needed to support military adaptation to climate change in inland regions?

4)What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure in inland region environments, in particular as a result of extended drought, more extreme precipitation and wind events, and altered fire and hydrologic regimes?

5) What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive risk assessment and response in arid region environments?

Session Chair: Ms. Kelly Burks-Copes, USACE

Breakout Session 3
Cross-Cutting Theme 1: Vulnerability and Impact Assessment/Adaptation/Climatology Research and Development Needs

Charge/Example Questions to Discuss

Overall charge: The 2010 Quadrennial Defense Review identifies the need for DoD to complete a comprehensive assessment of all installations to assess the potential impacts of climate change on its missions and adapt as required. In its initial Strategic Sustainability Performance Plan submitted to the Council on Environmental Quality in 2010, DoD identified a three-phase strategy to address its climate change risks and vulnerabilities. As a result, this session, in contrast to the regional focus of cross-cutting theme 1, looks at addressing climate change from a process perspective that shares many commonalities independent of region or resource or mission at risk. Group A will assess the processes of vulnerability and impact assessment. Group B will assess the processes of adaptation and mitigation. Vulnerability and impact assessment and adaptation are concerned with the question: what are we adapting to? Given the built-in inertia in the climate system that will compel some level of adaptation regardless of future emission reductions, mitigation concerns itself with reducing future adaptation liabilities. Finally, the military Services require better short-term and decadal predictions of changing climate phenomena to serve their operational purposes, sometimes in environments such as the Arctic that have complex ocean, ice, and atmospheric interactions. As such, DoD also plays a role in developing needed climate science, which will be in part the subject of Group C.

<u>Group A − Vulnerability and Impact Assessment</u>

Charge: Vulnerability of a military mission or of an installation's built and natural infrastructure to climate change is based on exposure (the location of concern is projected to experience some change in climate or an associated change such as sea level rise), sensitivity (the mission or infrastructure functionality would be sensitive to such a change), and adaptive capacity (degree to which the mission or infrastructure can or cannot accommodate to the change without significant functional impairment). Impact assessment considers a specific pathway of analysis that includes assumptions about climate drivers, whether probabilistic or scenario-based, environmental models, and impact assessment models, the last of which can be specific to military infrastructure, readiness, and operations. Having a clear understanding of potential impacts can provide a foundation for identifying necessary adaptation strategies.

Relevant ***questions*** include:

1) What scientific understanding, models, and tools are needed to conduct vulnerability assessments of DoD installations, especially if such assessments are conducted as a high level screen across installations or regions versus within installations or regions?

2) What scientific understanding, models, and tools are needed to conduct comprehensive impact assessments for vulnerable missions and installations?

3) What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive vulnerability and impact assessments?

4) How can science and technology developments from the research community relative to vulnerability and impact assessment be best transitioned to the implementation level and into operational practice?

Session Chair: Dr. Edmond Russo, USACE

<u>Group B − Adaptation and Mitigation Science</u>

Charge: The science of adaptation in the context of climate change is nascent, though it can build on a rich understanding from the engineering, ecological, and physical science disciplines as to how human and natural systems respond to environmental disturbances and stressors. When faced with uncertainty about the potential impacts of climate change, improving the resilience to stress of DoD natural and built infrastructure can be a no-regrets adaptation strategy. Because the future may present novel climates, built and natural systems may be exposed to climate extremes and variability never experienced. For natural systems we need a deeper understanding of how they respond to dynamic environments and for built infrastructure we may need to consider new design tolerances. Adaptation and mitigation are linked and strategies to reduce emissions may have unintended consequences that affect adaptive capacity.

Relevant ***questions*** include:

1) What scientific understanding, models, and tools are needed to advance the development of adaptation strategies?

2) What are the critical natural systems—whether they serve as protective barriers for other infrastructure or are needed for stewardship purposes—for which we need improved understanding of their dynamics under climate change to enhance their adaptive capacity and resilience?

3) What design features of DoD's built infrastructure should be assessed and modified for improving their adaptive capacity to a changing climate?

4) How can science and technology developments from the research community relative to adaptation be best transitioned to the implementation level and into operational practice?

5) What is the best mechanism to ensure planning documents and programs of record are informed on a regular basis by science and technology developments related to adaptation?

6) What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive the development of adaptation strategies, models, and tools?

Session Chair: Mr. William Goran, USACE

Group C − Climate Science (***This particular breakout session ended up not being convened***)

Charge: The military Services must be able to continue to operate as climate changes. Some environments, such as the Arctic, are areas of rapid change and will have complex responses to climate that may be poorly characterized by existing global models. DoD conceivably can have missions or activities anywhere in the world. Although much thought has been given to issues such as the Arctic and sea level changes, the spectrum of potential issues is vast and very site specific. The USGCRP has had a large and robust effort directed at long term climate change as related to human activity presumably forcing changes and is now beginning to look at issues related to downscaling of the larger patterns to regional and local scenarios and possible socio-economical impacts. These analyses will naturally address a broad range of issues relevant to many agencies and consequently may be of direct use to DoD. A major need of the Services will be climatologies that will be useful for meeting the Services' mission. This group will consider the types of climatologies that the services need in terms of time span (seasonal forecast to decadal forecast, for example) and spatial extent.

Relevant ***questions*** include:

1) Can we now specify regions/locations of highest interest and specify the temporal horizon?

2) Given the understandable uncertainty in climate forecasts, how can scientists best inform policy on the range of expectation and assure consistency in provision of information?

3) Do critical gaps exist that DoD sees in the climate science and particular its ability to deliver useful climatologies?

4) How can evolving policy and evolutionary science better inform each other on the intersection between climate science and DoD policy so that the appropriate climatologies can be provided in a timely way?

5) What are the critical partnerships that DoD must forge to get the information it needs?

Session Chairs: Dr. Scott Harper, Navy/Dr. Martin Jeffries, Navy

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APPENDIX C GLOSSARY

Key terms associated with the workshop and used in this report are provided below. Where appropriate the source citation is provided. Some definitions may be edited from the original to maintain a consistent editorial style. In addition, some terms are further annotated to provide additional context.

Adaptation—Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects (NRC 2010).

***Adaptive capacity*—**Ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Parry et al. 2007).

Built infrastructure—Basic equipment, utilities, productive enterprises, installations and services essential for the development, operation, and growth of an organization, city, or nation (based on Parry et al. [2007] definition of infrastructure). All building and permanent installations necessary for the support, redeployment, and military forces operations (e.g., barracks, headquarters, airfields, communications, facilities, stores, port installations, and maintenance stations (based on JP1-02 [2001] definition of infrastructure).

Climate—In a narrow sense is usually defined as the 'average weather,' or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (Parry et al. 2007).

***Climate change*—**Refers to any change in climate over time, whether due to natural variability or as a result of human activity. [Anthropogenic] climate change, as defined by the United Nations Framework Convention on Climate Change, refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (based on Parry et al 2007).

Climate (change) scenario—Plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A 'climate change scenario' is the difference between a climate scenario and the current climate (Parry et al. 2007).

***Climate system*—**Defined by the dynamics and interactions of five major components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Climate system dynamics are driven by both internal and external forcing, such as volcanic eruptions, solar variations, or human-induced modifications to the planetary radiative balance, for instance via anthropogenic emissions of greenhouse gases and/or land-use changes (Parry et al. 2007).

Climate variability—Refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability*)*, or to variations in natural or anthropogenic external forcing (external variability) (Parry et al. 2007).

Downscaling—Method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses (Parry et al. 2007).

For climate information downscaling can be accomplished by either statistical or dynamical (regional climate model) means.

Extreme weather event—Event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' differ, but an extreme weather event would normally be as rare as or rarer than the 10^{th} or 90th percentile. By definition, the characteristics of what is called 'extreme weather' may differ from place to place. Extreme weather events may typically include floods and droughts (Parry et al. 2007).

Impact assessment—Practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change [and climate variability] on natural and human systems (Parry et al. 2007).

The preceding implies a form of quantitative assessment, in which some degree of specificity in the associated climate, environmental (biophysical) process, and impact models, accompanied by an evaluation of the uncertainties involved, is a necessary and integral contribution to reported outcomes. Likely requires high quality and spatially granular data. Impact assessment may lead to identification of adaptation strategies that can reduce system vulnerabilities.

Likelihood—Likelihood of an occurrence, an outcome, or a result, when this can be estimated probabilistically (Parry et al. 2007).

***Mitigation*—**Intervention to reduce the causes of changes in climate, such as through reducing emissions of greenhouse gases to the atmosphere (NRC 2010). An anthropogenic intervention to reduce the anthropogenic forcing of the climate system, which includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks (Parry et al. 2007).

The preceding definitions differ substantively from and shouldn't be confused with the 40 CFR 1508.20 definition of mitigation, which considers a hierarchical approach and includes the concepts of avoiding environmental impacts, minimizing impacts, rectifying the impact, reducing or eliminating the impact over time, and compensating for the impact.

Natural (green) infrastructure—Concept that highlights the importance of the natural environment in decisions about land-use planning. In particular, an emphasis is placed on the 'life support' functions provided by a network of natural ecosystems, with an emphasis on interconnectivity to support long-term sustainability. Examples include clean water and healthy soils (Wikipedia; accessed 14 August 2011).

In a DoD context, the concept can be extended to include those features of the land and water environments, including their biota and associated ecological processes, that directly or indirectly support military readiness or serve protective functions for built infrastructure during extreme weather events. In the first case, natural ecological systems often provide needed training landscapes and training realism. These can range from the permafrost-controlled ecological systems of Alaska to the barrier islands off the coasts of several military installations. In the second case, coastal wetlands and barrier islands serve to protect mainland areas from the effects of storms.

***Resilience*—**Capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment (NRC 2010). Ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, capacity for self-organization, and capacity to adapt to stress and change (Parry et al. 2007).

***Risk*—**Combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur (NRC 2010).

Sensitivity—Sensitivity is the degree to which a system may be affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (Parry et al. 2007).

Vulnerability—Degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes (NRC 2010). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (Parry et al. 2007).

Vulnerability assessment—Practice of identifying and evaluating the effects of climate change and climate variability on natural and human systems so as to understand system sensitivities and capacity to adapt (defined herein).

As one possible approach to distinguish a vulnerability assessment from an impact assessment, the above definition and the preceding one for vulnerability together can be interpreted to imply a form of qualitative assessment or at least a less rigorous quantitative assessment, in which the degree of specificity in the climate, environmental (biophysical) process, and impact models, even when accompanied by an evaluation of the uncertainties involved, is not as stringent as for an impact assessment. Moreover, from this perspective, data requirements, including their spatial granularity, can be more relaxed than what is required for an impact assessment. Vulnerability assessments, when defined this way, may best be tied to an initial screening process that may lead to the more detailed impact assessments for those locales and systems identified as most vulnerable or critical to mission.

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APPENDIX D LIST OF ACRONYMS/ABBREVIATIONS

AMOP	Administrative Modeling and Oversight Panel
APG	Arctic Policy Group (led by Department of State)
ASA(ALT)	Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology
ASA(CW)	Office of the Assistant Secretary of the Army for Civil Works
ASA(IE&E)	Office of the Assistant Secretary of the Army for Installations, Energy, and the Environment
BROMEX	BRomine, Ozone, and Mercury EXperiment
CEQ	Council on Environmental Quality
CESM	Community Earth System Model
CNA	Center for Naval Analyses
CONUS	Continental US
CRREL	Cold Regions Research and Engineering Laboratory
DEM	Digital Elevation Map
DoD	Department of Defense
DSB	Defense Science Board
EO	Executive Order
ERDC	Engineer Research and Development Center
ESMF	Earth System Modeling Framework
ESPC-RDO	Earth System Prediction Capability-Research, Development, and Operations
ESTCP	Environmental Security Technology Certification Program
FEMA	Federal Emergency Management Agency
GCC	Global Climate Change
GCM	General Circulation Model
GHG	Greenhouse Gas
HQ	Headquarters
HYCOM	Hybrid Coordinate Model
IMCOM	(Army) Installation Management Command
INCATF	Interagency National Climate Assessment Task Force (now Workgroup)
INRMP	Integrated Natural Resources Management Plan
JCTD	Joint Capability Technology Demonstration
JUONS	Joint Urgent Operational Needs Statements
NAVFAC ESC	Navy Facilities Engineering Command Engineering Service Center
NAVSEA	Naval Sea Systems Command
NCA	National Climate Assessment
NDIA	National Defense Industrial Association
NCCCO	Navy Climate Change Coordination Office
NMFWA	National Military Fish and Wildlife Association
NOAA	National Oceanic and Atmospheric Administration
NOC	National Ocean Council
NOPP	National Oceanographic Partnership Program
NPS	Naval Postgraduate School
NRC	National Research Council

NRL	Naval Research Lab
NSB	Naval Studies Board
NSF	National Science Foundation
NUMA	Non-hydrostatic Unified Model for Atmosphere
NUOPC	National Unified Operation Prediction Capability
NWC	Naval War College
OAML	Oceanographic and Atmospheric Master Library
ODASA(ESOH)	Office of the Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health)
OPNAV	Office of the Chief of Naval Operations
OSD	Office of the Secretary of Defense
OSD(I&E)	OSD(Installations and Environment)
OSD(TRS)	OSD(Training Readiness and Strategy)
ONR	Office of Naval Research
PACFLT	Pacific Fleet
POM	Program Objective Memorandum
PSP	Polar Science Program
QDR	Quadrennial Defense Review
REC	Regional Environmental Coordinator
RCM	Regional Climate Model
R&D	Research and Development
RTP	Rapid Transition Program
SAF/IE	Office of the Assistant Secretary of the Air Force (Installations, Environment and Logistics)
SAF/IEE	Deputy Assistant Secretary of the Air Force (Environment, Safety and Occupational Health)
SAME	Society of American Military Engineers
SERDP	Strategic Environmental Research and Development Program
SSPP	Strategic Sustainability Performance Plan
STEM	Science, Technology, Engineering, and Mathematics
TFCC	Task Force Climate Change
TFCC ESC	Task Force Climate Change Executive Steering Committee
TW	Trident Warrior
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USFF	U.S. Fleet Forces
USGCRP	U.S. Global Change Research Program
USNA	U.S. Naval Academy

Appendix E Compendium of Department of Defense Research and Development Programs Related to Climate Change

US Department of Defense

Strategic Research and Development Program (SERDP), Resource Conservation and Climate Change Program Area

Climate change will play a significant role in the Department of Defense's (DoD) ability to fulfill its mission in the future. It will affect both built and natural infrastructure, which will impact readiness and environmental stewardship responsibilities at hundreds of installations across the nation. SERDP investments are developing the understanding and tools necessary to identify vulnerable assets, assess impacts, and determine appropriate adaptive responses.

Climate-related effects already are being observed at DoD installations in every region of the United States and its coastal waters. These physical changes include:

- rising temperature and sea level
- increases in both heavy downpours and the extent of drought
- thawing permafrost
- shifts in growing seasons
- lengthening ice-free seasons in the oceans and on lakes and rivers
- earlier snowmelt
- altered river and stream flows.

The direction, degree, and rate of these changes will differ by region, as will the impacts to the military's infrastructure and capabilities. SERDP investments are improving the understanding of the potential impacts of climate change and developing effective adaptation and mitigation strategies that will enable DoD to respond appropriately.

SERDP investments are focused on the following:

Vulnerability and Impact Assessment—Quantifying climate change impacts requires understanding how physical drivers, such as sea level rise and extreme weather events, will change. It also involves determining which components of DoD infrastructure are potentially vulnerable to these changes and how they could be affected. Another essential aspect is an improved understanding of how species and ecosystems associated with DoD lands and waters will respond to climate change in the context of other stressors. The primary emphasis of research is the development of region-specific tools and models to better predict the impacts both to the features that protect coastal areas and to the built infrastructure of installations, ranges, and the surrounding communities. Research to be initiated in FY12 will take a broad view and investigate the role of various decision frameworks and their ability to match climate information to the needs of DoD infrastructure managers.

Adaptation Science—Adaptation to climate change involves reconfiguring DoD's natural and built infrastructure or increasing its resilience. Research is focused on improving the understanding of how to manage species and ecosystems that will be affected by climate change. Certain types of natural infrastructure provide physical protection from extreme weather events

for training and testing areas and built infrastructure. Research involves studying how to enhance the resistance, resilience, or recovery capacity to enable such natural infrastructure to continue to provide benefits in the face of climate change.

Land Use and Carbon Management**—**Land-use practices affect the rates of carbon cycling and storage within the soil and vegetation. Research initiated in FY 2011 will improve the understanding of carbon cycle dynamics across the various landforms and vegetation types that DoD manages. This knowledge can be used to ensure land and carbon management is compatible with maintaining military mission support, desired ecosystem services, and biological diversity.

Department of Defense, Legacy Resource Management Program

The DoD Legacy Resource Management Program (Legacy) funds natural and cultural resources projects with national, regional or other wide-scale DoD applications to support overall DoD conservation goals and military readiness. Legacy helps protect and manage these resources to ensure continued access to realistic habitat conditions that support the military's combat readiness mission, while fulfilling its stewardship responsibilities. Legacy has funded several climate change-related projects in the past three years.

Guidelines for Assessing the Vulnerability of Species and Habitats to Climate Change**—**These guidelines describe ways to assess the vulnerability of plants and animals to anticipated changes in climate. The information is intended to help DoD natural resources managers better manage those species and habitats most likely to need conservation actions as a result of expected changes.

Sea Level Rise Risk Assessment for DoD Coastal Installations**—**This project assessed the risk of sea level rise to natural, cultural, and operational resources at five DoD installations on the Dare County peninsula in North Carolina. The assessments were made using the Intergovernmental Panel on Climate Change moderate sea level rise scenario, and showed that major training interruptions could potentially begin as soon as 2050, when forestland converts to wetter marsh transition vegetation.

Modeling the Impacts of Climate Change on Birds and Vegetation on Military Lands**—**These models predict and map how climate change may alter vegetation and bird distribution on DoD lands in California. Vegetation and bird losses are projected to be much greater on DoD lands than on other public lands in California, as birds and vegetation are significantly more abundant and diverse on DoD lands. If regional changes in climate result in declines of already at-rick species on military installations, those species could become federally listed. This could lead to potential impacts to testing and training activities.

Climate Change Tools Workshop**—**The DoD Natural Resources Program sponsored the *Climate Change Tools for Adapting Management Strategies* workshop at the 2010 National Military Fish and Wildlife Association (NMFWA) annual meeting. This workshop described currently available tools and provided information on how and when to use them appropriately. Specifically, the workshop:

- educated DoD natural resources personnel about tools that are, or will soon be, available to help them adapt management activities in light of anticipated climate change impacts;
- described how and when to use these various tools; and
- guided them through the use of these tools.

DoD Animation on Climate Change Activities—The video introduces the issue of climate change and features projects on sea level rise and threatened and endangered species, as well as an overview of DoD's conservation funding programs. The animation and an accompanying fact sheet are available at www.dodnaturalresources.net.

US Department of the Army

Research and development (R&D) on the topic of climate change within the Army is executed by the U.S. Army Engineer Research and Development Center (ERDC). The relevant R&D activities are focused on developing capability to understand and inform decisions related to the consequences of climate change and variability on Army installations, assets, and infrastructure. Research concerned with the effects of climate change on military installations is primarily supported by the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)). The Office of the Assistant Secretary of the Army for Civil Works (ASA(CW)) and US Army Corps of Engineer (USACE) Headquarters (HQ) support research at ERDC in the areas of coastal and inland water infrastructure and ecosystems.

Research Supporting Military Installations

Within the thrust areas of Sustainable Ranges and Lands and Military Materials in the Environment, research is being conducted in three areas.

Prediction and Adaption of Military Infrastructure in Response to Climate Change—The objective this R&D is to develop advanced ecological network models for vulnerability assessments of mission critical ecosystem processes impacted by climate change. The ecological components considered are those that constrain military mission including regulatory constraints (e.g., endangered species, invasive species, and erosion) and aspects of community structure and function critical for training missions (e.g., "vegetation encroachment"). Climate drivers for these models will be obtained from previously developed general circulation models (GCM) and regional climate models (RCM), including those used or developed in other ERDC research activities. Ecological network models will incorporate data from previously completed research projects. Developed models are intended for use in existing modeling frameworks and/or emerging systems. The current effort targets model development for installations in the southeastern U.S., specifically the Sandhills region.

Climate Change-Induced Biome Shifts and Contaminant Management Implications for DoD Lands—The objective of this project is to build a toolkit for use in ecological risk assessment, sustainable contaminant management, and remediation activities. This project will utilize existing regional biome-shift models to predict significant changes in conventional knowledge of contaminant fate, transport, and biological impact due to climate change and related stressors for ecological risk assessment at continental US (CONUS) installations. Biome models cover larger geographic regions as compared to typical ecosystem models and are characterized by a

focus on specific dominant organisms. Specifically for this effort, vegetative dominant biome-shift models will be utilized as the most influential factor on soil properties and change in contaminant behavior. Although changing climate will affect individual species and populations, the whole will be more than the sum of the parts. Landscape conversion produced by passive biome shift with or without altered disturbance regimes, or a more dynamic synergy between climate change and anthropogenically induced stressors, will cause upheavals in community assemblages, interspecies relationships, and biological processes.

***Integrated Modeling and Risk Analysis for the Environmental Consequences of Climate Change: A Framework for Assessing the Environmental Effects of Climate Change for the Military*—**This project is developing an integrated technology platform for modeling and analyzing the influence of climate change on environmental impacts of interest to military planners and decision-makers. The analytical framework integrates rigorous, large-scale models of the global climate system with analytically tractable model linkages to regional assessments of climatic change, weather, ecological stressors, watershed processes, and landscape evolution. A diverse range of environmental impacts are explored in terms of their potentially deleterious effects on ecosystems associated with military installations and the missions they support. All of these components are integrated within a risk-based decision analytic framework that provides military planners with a robust computational environment for formally evaluating a broad range of possible response, mitigation, and adaptation strategies.

Research Supporting the USACE Civil Works Mission

ERDC conducts a range of research, funded by multiple research programs, in support of USACE Civil Works program missions related to coastal and flood infrastructure, navigation systems and infrastructure, and ecosystem restoration. The relevant physical research includes the development of hydrologic and hydrodynamic models for characterizing wave processes in coastal environments, flooding and inundation, sediment transport, and a variety of other processes. The environmental research supporting both the navigation and restoration missions includes processes and modeling affecting water and sediment quality as well as ecological processes at a variety of scales.

US Department of the Navy

Research and development (R&D) on the topic of climate change within the Navy is executed by a number of organizations.

Task Force Climate Change

Navy's Task Force Climate Change (TFCC) is the principal Navy organization responsible for developing policy, requirements, and identifying Navy research requirements regarding climate change science, mitigation, and adaptation. All Navy components have representatives on TFCC who identify their organization's needs and questions regarding climate change science and research. These needs exist on spatial scales from sub-regional to global and on operational scales from tactical to strategic. As a result, a wide range of needs exists, including the development and implementation of mission/operational/campaign plans, infrastructure/facilities plans, education and outreach, policy development, development of Naval platforms, weapons and sensors, and the investments associated with these efforts.

Office of Naval Research

Although the Office of Naval Research (ONR) does not fund research for the purpose of understanding or predicting climate change, ONR supports basic research programs that, while directed toward fulfilling the objectives outlined in the Naval Science and Technology Strategic Plan, also project onto the science goals needed for the U.S Navy to understand a changing physical environment and maintain readiness. ONR has developed initiatives that will improve monitoring and prediction of critical environmental changes in the Arctic, including the marginal ice zone in which the Navy and Coast Guard may be required to operate.

Naval Research Laboratory

The Naval Research Laboratory (NRL) Oceanography, Remote Sensing, Marine Geosciences, and Space Science Divisions conduct research and development related to climate in the following areas: (1) basic research related to climate change, (2) applied research in development of prediction systems for changing climate, and (3) multi-agency R&D related to climate change. Each of these areas is described in additional detail below.

Basic Research Related to Climate Change—Includes the following research areas:

- Improving understanding of the changing Arctic environment, including the study of the influence of air-sea interaction on the development and propagation of global tropical instabilities, such as the Madden-Julian Oscillation.
- Determining how future changes in the operational environment could impact Navy and Marine Corps policy, strategy, force structure, and investment. This research uses state-of-the-art earth system prediction models to explore the following areas: (1) modeling feedbacks between Arctic sea ice and vertically deep atmospheric circulations to better understand observed trends; (2) quantifying the impact of increased frequency of extreme weather on installations and operations worldwide; (3) developing better parameterizations of physical processes to improve the skill of numerical climate and weather prediction systems; and (4) performing observations-based statistical modeling to quantify natural sources of climate variability, such as solar cycle influences on surface temperatures and upper atmospheric densities.
- Identifying cycles/trends in solar irradiance and their impact on climate. Multi-year data regression studies are showing resonant responses and positive feedbacks in the ocean-atmosphere system that may amplify response to solar irradiance variations. These cycles and trends are becoming recognized as important components of natural climate variability on decadal to centennial scales. Research in this area examines the linkage between solar irradiance in relation to other natural and man-made phenomena impacting terrestrial climate variability. This research is funded by a non-DoD source.
- Establishing the capability to measure soil moisture. Soil moisture is a key climate variable in the global water, energy, and carbon cycles and in environmental assessment and prediction.

Applied Research in Development of Prediction Systems for Changing Climate—Includes the following research areas:

- Adding an ice predictive capability to the Navy's new global ocean model, the Hybrid Coordinate Model (HYCOM), to predict (7 days) ice conditions for the Arctic and the Antarctic, which is called the Navy's Arctic Nowcast/Forecast System or the Arctic CAP model. The intent is to repeat this demonstration next year and contribute these results to the Search Sea Ice Outlook community-wide published summary for the expected September arctic sea ice minimum in FY12 (http://www.arcus.org/search/seaiceoutlook/).
- Developing the next generation atmosphere prediction model, the Non-hydrostatic Unified Model for Atmosphere (NUMA). The design of NUMA is aimed for a seamless, unified numerical prediction suitable for both short-term (< 2 weeks) weather and long-term (to decadal) climate prediction.
- Using data from the NRL WindSat instrument to develop an optional capability to monitor the sea ice extent and concentration from space. The data streams are fed into the National Ice Center (NIC) for distribution to users from scientific and operational communities.

Multi-Agency R&D Related to Climate Change: Includes the following research areas:

- Supporting the multi-agency National Unified Operation Prediction Capability (NUOPC) by building the framework for coupling the global atmosphere model, NAVGEM, with the global ocean circulation model, HYCOM, using the Earth System Modeling Framework (ESMF). This infrastructure paves the road for longer-term prediction as the atmosphere, ocean, ice, land, and space components are seamlessly coupled to form a whole earth system. A follow-on effort is proposed to couple together the Navy's global atmosphere model, global ocean model, and global wave model to create a system for longer-term prediction that will provide consistent forecasts of the atmosphere, ocean, and wave state for operational and tactical planning beyond the current capability.
- Participating in the multi-agency Earth System Prediction Capability-Research, Development, and Operations (ESPC-RDO) initiative. The goal of ESPC-RDO is to develop a new operational global earth system model consisting of high-resolution atmosphere, ocean, ice, land, and space components capable of seamless prediction from zero hour to three decades within the next ten years. Related to this initiative, NRL has proposed to study the seasonal prediction with a focus on the impact of model resolution on multi-scale simulations. This research will set the foundation for the development of the seamless weather-climate ESPC-RDO.

Naval Postgraduate School

The Naval Postgraduate School (NPS) is a graduate level research university located in Monterey, California. NPS operates in many ways like a civilian research university but with a focus on DoD relevant basic and applied research and on corresponding graduate-level education (masters of science and doctoral studies and research). NPS conducts basic and applied research and development projects on a wide range of climate topics, including: studies of the local, regional, and global atmosphere, ocean, and land; studies of specific phenomena (e.g., storms, floods and droughts, ocean circulation, and sea ice process); long term data collection and analysis; climate model development and testing (e.g., statistical, dynamical, statistical-dynamical, multi-model, and multi-decadal hindcasting and verification); climate system prediction (intraseasonal to multi-decadal lead times); performance prediction (e.g., prediction of sensor and weapons performance); operational impacts of climate change (e.g., impacts on

infrastructure, sensors and weapons, personnel, planning—tactical, operational, and strategic, and national and international policy). Climate change is covered in several climate science courses, numerous other meteorology and oceanography courses, and also in operations analysis, national security, and defense analysis courses. NPS graduate students conduct masters and doctoral research studies on these topics and on the application of research and development results to the Fleet. NPS research and development addresses climate issues in the areas of responsibility for all the Combatant Commands.

United States Naval Academy

The United States Naval Academy (USNA) conducts research and teaches classes that incorporate global climate change. The Oceanography Department offers two dedicated climate-themed courses, Global Climate Change and Polar Oceanography. The Oceanography Department is taking the lead in the development of a USNA field research-based Polar Science Program (USNA PSP), with contributions from the Ocean Engineering, Systems Engineering, and Computer Science Departments that will greatly enhance midshipman education and research. At the core of this effort is the development and maintenance of a USNA PSP Arctic buoy, which will be built and deployed by midshipmen as a collaborator in the BRomine, Ozone, and Mercury EXperiment (BROMEX 2012; http://seaice.apl.washington.edu/AirChemistry/). This field experiment will take place in Point Barrow, Alaska during March of 2012. Midshipmen and USNA faculty also will conduct field research on seismo-acoustic characterizations of ice lead ruptures and collisions and linked land-sea-air-ice chemistry in support of BROMEX 2012 science objectives. Results and lessons learned from BROMEX 2012 will provide the basis for continued USNA PSP and midshipman involvement in ongoing national and international Polar research projects. As a related effort, the USNA PSP will provide a basis to promote and enhance current and planned USNA Science, Technology, Engineering, and Mathematics (STEM) initiatives specifically in the realm of Polar Science.

USNA professors are conducting research on the flood risk associated with coastal storms in combination with sea level rise. Work has been funded by US Army Corps of Engineers to provide engineering design guidance for sea level change as it relates to the Corps' mission of national flood damage reduction. Emphasis is on regional comparison of 28 cities around US coast to define differences in flood risk and vulnerability to different sea level rise scenarios as outlined in recent Corps design guidance to field offices.

Senior Ocean Engineering Capstone design project to develop feasibility-level design of an Alaska Arctic Deep Water Port. Midshipmen from USNA are pursuing concept-level design for a new port to support joint US Coast Guard and commercial operations in Arctic Alaska. The study will consider site selection, port size and operational capacity, port layout and need for breakwater protection, and dredging requirements.

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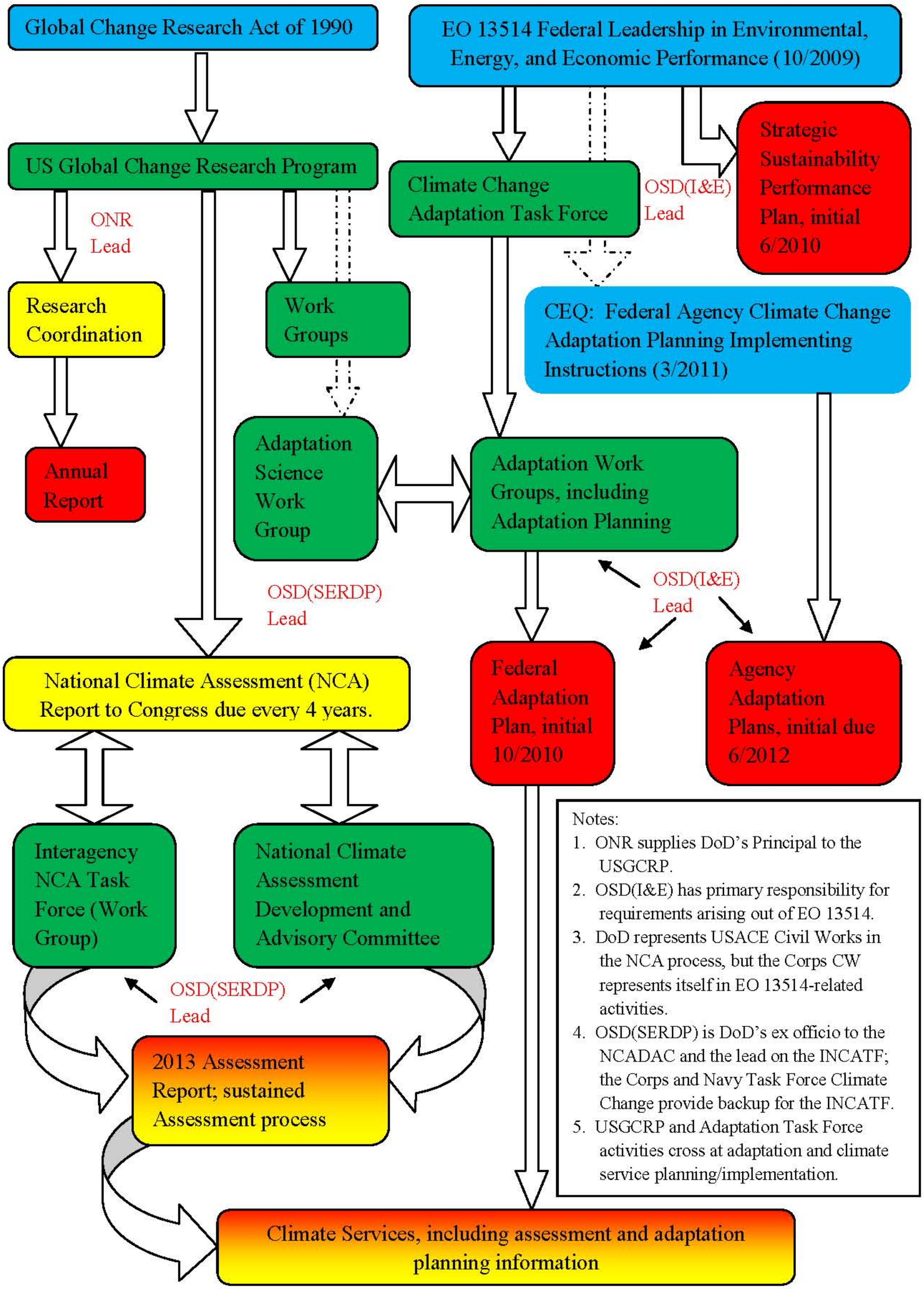
APPENDIX F FEDERAL CLIMATE CHANGE RESEARCH AND DEVELOPMENT AND RESPONSE DRIVERS AND NETWORK



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Appendix G Breakout Session Summaries

G1 Service Breakout: Army/Air Force

Breakout Session 1
Service Breakouts

Army/Air Force
Session Chair: Dr. Todd Bridges, USACE ERDC-EL

Organizational Relevance

The Army and Air Force are both engaged in organizational activities with respect to the generation and use of climate change information. Within the Army, the four elements currently engaged include the Army Installation Management Command, IMCOM; the Office of the Assistant Secretary of the Army for Installations, Energy and the Environment, ASA(IE&E); The Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, ASA(ALT); and the Office of the Assistant Secretary of the Army for Civil Works, ASA(CW). Within the Air Force, climate change is currently being addressed within the Office of the Assistant Secretary of the Air Force for Installations, Environment and Logistics (SAF/IE).

The relevance of climate change information for Army IMCOM, the ASA(IE&E), and the SAF/IE relate to their complementary roles in policy development, planning, and management pertaining to military installation infrastructure, both natural and built, within the U.S. and elsewhere. Climate change and variability will pose challenges to the performance and reliability of aging infrastructure delivering energy and water to installation communities; it will also exacerbate stressors affecting natural systems and environmental resources comprising training lands and ranges.

The ASA(CW), through the U.S. Army Corps of Engineers (USACE), oversees the development and management of a large network of water resources infrastructure (including navigation channels, locks and dams), reservoirs, both inland and coastal infrastructure related to flood risk management, as well as a series of large-scale ecosystem restoration projects. Climate change and variability, as these affect the spatial and temporal distribution of precipitation and storm activity within the U.S., will pose significant challenges and risks to the performance of such water resources infrastructure and investments.

Both the Army and USACE are currently investing in research related to assessing the impacts of climate change and their management. The ASA(ALT) supports environmental research related to the management of technology development and Army operations, which includes consideration of climate change impacts relevant to Army missions. The U.S. Army Engineer Research and Development Center (ERDC) holds the lead role for conducting environmental research supporting both the Army's military and civil works missions, including climate change. As such, ERDC is currently conducting research to expand the Army's and USACE's capabilities to assess and manage risks related to climate change and variability. The USACE Institute for Water Resources is supporting the ASA(CW) through the development of policy for

using existing science on coastal and inland hydrology, sea level change, flood frequency analysis, reservoir sedimentation, and droughts and other climate related topics.

Engagement on the topic of climate change is also relevant to the DoD's Regional Environmental Coordinators (RECs). In 1994, the DoD established 10 multi-state RECs to improve environmental coordination at the regional, state and local levels. The RECs provide DoD and the installations a centralized voice and act as the bridge between DoD, environmental regulators and the states. DoD split the lead role for individual regions among the Army, Navy and Air Force. RECs act as liaisons among any number of agencies and entities concerned with the environment on and around military installations. They coordinate with federal, state and local environmental regulators; state legislators; non-governmental organizations; the Installation Management Agency, other DoD entities; and Native American tribes. They communicate via conferences, forums and newsletters. The RECs facilitate partnerships and collaboration efforts within and among these groups. An example of the relevance of climate change to the evolving mission of the RECs is the Army's new Strategy for the Environment which sets forth the triple bottom line of sustainability: mission, environment and community. RECs work to reach this bottom line by opening lines of communication, coordinating efforts, and facilitating solutions to ensure the readiness of the Army and the well-being of people and the environment now and into the future.

Needs, Opportunities, and Relationships to USGCRP and NCA

While progress continues to be made in organizing climate change initiatives and policy within the headquarters of DoD and the Services, plans for distributing these products within and between the Services as well as with organizations external to DoD will need to be developed. Current needs within the Army and Air Force include the development of relevant requirements for climate change indicators that can be used to identify trends, thresholds, or impacts related to climate change for which engineering or management actions should be formulated. In addition, new policies and analytical capabilities will be needed to support coherent adaptation strategies that minimize costs and risks to mission critical functions over time. Engagement between the R&D communities within the Army and Air Force and the USGCRP and the NCA can facilitate both the communication of DoD's needs within the broader technical community while providing the DoD ready access to expertise and technology across the federal government. The USACE Chief Scientist, as Director of ERDC and the Director of USACE R&D, could serve as a point of engagement between the Army's research and development (R&D) activities and the R&D activities of other federal organizations participating within the USGCRP and the NCA.

As a part of this engagement process, the RECs could play an important role in identifying regional input to the development of requirements within the headquarters of DoD and the Services. The RECs may also provide a logical engagement point for regional assessments being conducted as a part of the NCA. Given the importance and challenges associated with stakeholder engagement in relation to climate change, the stakeholder networks developed by the RECs should provide an efficient and effective means for fostering the coordination and communication needed to move forward with the actions comprising a local or regional climate change adaptation plan.

Climate Change Future Needs Driving R&D Requirements

The following provides a list of R&D needs/requirements that were identified as germane to the Army and Air Force during the workshop.

- **Processes**
  - Using long-term physical lines-of-evidence (e.g., tree rings) in combination with process models to characterize trends for regional up-scaling that support global circulation mode (GCM) scenario-based regional downscaling.
  - Evidence to support predictions of momentum for how long climate change effects related to greenhouse gas (GHG) production (both duration and magnitude) will occur. Such evidence is needed to develop predictive capabilities for explaining incremental costs and consequences for emission scenarios and other influences.
  - Understanding climate change impacts on aircraft dynamics and sensor performance in new and legacy systems.
  - Higher resolution digital elevation maps (DEMs) and water level gauging to support climate change R&D.

- **Analytics**
  - Improved approaches for predicting and characterizing climate change effects and impacts to a level of acceptable uncertainty.
  - Methods for developing and then testing the efficacy of adaptation strategies and operational practices devised to address the predictions associated with climate change research.
  - Quantification methods for characterizing uncertainty in predictions.
  - Quantification of variability with respect to infrastructure operational/performance thresholds.
  - Downscaling that is sufficient for evaluating hydrologic system response.
  - Improved understanding for determining which variables matter most in decisions.
  - Guidance to support how to use climate change information to best inform decisions.
  - Downscaling to improve understanding of hazards and impacts.
  - Economic and budget analysis for supporting cost-benefit analysis under high levels of uncertainty.
  - Understanding of complex interactions of systems to characterize potential unintended consequences.
  - Ability to downscale GCMs to a reasonable level of uncertainty to inform hazard event modeling simulation regionally.
  - Engineering guidance for infrastructure adaptation.
  - Agreement on which GCMs the scientific community should be using.
  - New definition of return period for hazard events.
  - Better GCM regional downscaling and impact assessment to identify infrastructure related requirements.
  - Improved decision analytics to support rational identification and implementation of adaptive management actions.

- **Future Conditions**
  - Prediction of future water demands on a geographical basis.

- Identification of common future climate change scenarios for DoD Services and regions to apply in planning.
- Identification of environmental tipping points with lead times for effective management.
- Non-stationarity lookup tables of conditions anticipated in the future for use in scenario development.
- Predictive knowledge for how climate change is currently and will affect DoD Services' missions.

Using Climate Change Information

The Army and Air Force expect to use climate change information in the following ways:

- Increasing the situational awareness of senior leadership on climate change phenomena and potential Service vulnerabilities and global risks at the strategic level.
- Risk assessment and identification of management actions that can be taken to reduce risks to the portfolio of Service assets, infrastructure, and missions at the full range of scales: globally, regionally, and locally.
- Technology transfer of tools to operational end users at installations to support the development of local strategies and plans to address the projected consequences of climate change, including adverse effects caused by extreme events.

G2 Service Breakout: Navy

Breakout Session 1
Service Breakouts

Navy
Session Chair: CAPT Tim Gallaudet, USN, OPNAV/TFCC
Assistant Chair: Dr. Tom Murphree, NPS

Navy attendees at the workshop included representatives from the Chief of Naval Operations (OPNAV) staff (Task Force Climate Change/Oceanographer of the Navy), the Naval Postgraduate School (NPS), the Office of Naval Research (ONR), the Naval Research Lab (NRL), Naval Facilities Engineering Command (NAVFAC ESC), and others. The following provides a summary of the breakout session findings by question, followed by additional issues and questions raised by session attendees.

Charge Question 1: Who (person or office) in your Service is interested in and should receive updates on USGCRP or may want to present needs or questions to the DoD USGCRP representative so he can query USGCRP relative to the federal investment in climate change science and its relevance to the DoD/military Services? (The goal is to develop the basis of a communication "wiring" diagram, so names, email, office symbol would be useful in the listing.)

The Navy's Task Force Climate Change (TFCC) is the principal Navy organization responsible for developing policy and requirements and identifying Navy research requirements regarding climate change adaptation, mitigation, and science. Within TFCC, the Navy Climate Change Coordination Office (NCCCO) under the Chief of Naval Operations Staff (OPNAV N2/N6E) acts as the central point of contact and administrative office to coordinate climate change requirements and policy across the Navy.

All Navy components have representatives on TFCC that report to the NCCCO, and their Flag/SES representatives are members of the TFCC Executive Steering Committee (ESC), which is chaired by the TFCC Director (Oceanographer of the Navy – OPNAV N2/N6E) and charged with providing the Chief of Naval Operations with recommendations regarding climate change related policy, requirements, and investments.

Navy components represented on TFCC that have needs and questions regarding climate change science and research include USFF/PACFLT/Fleet Commanders, Commander Naval Installations Command and the Navy Region Commanders, Navy Resource Sponsors and Offices on the Chief of Naval Operations Staff (e.g., Information Dominance, Surface/Aviation/Submarine/Expeditionary Warfare, Naval Medicine, Naval Reserves), Office of Naval Research (DoD's USGCRP representative), Naval Research Lab, Naval Postgraduate School, Naval War College, and U.S. Naval Academy.

Despite the institutional representation by TFCC for climate change issues across the Navy, several challenges exist for effectively communicating climate change science needs to the TFCC NCCCO, ONR, and USGCRP, including challenges concerning climate education within

the Navy component staffs, sufficiency of resources and staffs, prioritizations, and perceptions of relevancy.

Areas of climate change science and research of interest within the Navy are diverse and can be divided into: (1) basic physical science relevant to strategic, operational, and tactical planning and (2) applied science and engineering related to installation and platform and system adaptation. Examples of the former include understanding and predicting the physical mechanisms of oceanic, atmospheric, and terrestrial climate change on regional to global scales, including complex feedback mechanisms associated with, for example, abrupt climate change and tipping point phenomena.

Charge Question 2: The next National Climate Assessment is now underway with a target date of a 2013 report to Congress. Included may be updates to or new assessments at the regional scale. Who (person or office) in your Service is interested in and should receive updates on opportunities to participate in regional assessment activities? (The goal is to provide a list of interested offices/participants by region through the DoD Interagency National Climate Assessment Task Force representatives.)

As indicated above, the Navy's Task Force Climate (TFCC) Navy Climate Change Coordination Office (NCCCO) is the lead Navy office that would participate in regional assessments, coordinate with TFCC representatives from the Navy Regional Commands and Fleet Commander staffs, and interact with other Navy organizations that might need to be aware of and/or participate in regional assessments (e.g., Office of Naval Research (ONR), Naval Research Lab (NRL), Naval Postgraduate School (NPS), Naval War College (NWC), U.S. Naval Academy (USNA), and Naval Facilities Engineering Service Center (NAVFAC ESC)). TFCC will prepare a contact information list for these organizations.

Charge Question 3: What research or activities is your Service, either internally or though extramural funding, actively conducting or planning to conduct that are related to climate change vulnerability and impact assessment, adaptation science, mitigation, or climate modeling? (The goal would be a list of what is underway or planned, where/who, and the requirement being addressed.)

The Navy has several ongoing and planned activities related to climate change vulnerability and impact assessment, adaptation science, mitigation, and climate modeling. Organizations sponsoring or contributing to this work include the Office of Naval Research (ONR), Naval Research Lab (NRL), Naval Postgraduate School (NPS), Naval War College (NWC), U.S. Naval Academy (USNA), Naval Facilities Engineering Service Center (NAVFAC ESC), Task Force Climate Change (TFCC)/Oceanographer of the Navy, and Office of the Secretary of Defense (OSD) Strategic Environmental Research and Development Program (SERDP). The following briefly summarizes these activities:

- Task Force Climate Change (TFCC)/Oceanographer of the Navy: Assessment of Naval coastal installation vulnerability to sea level rise.
- The Office of the Secretary of Defense (OSD) Strategic Environmental Research and Development Program (SERDP): Multi-disciplinary studies of climate change impacts to military installations in the continental United States (CONUS).

- Office of Naval Research (ONR): Participation in an interagency, advanced Arctic and global numerical environmental prediction program, including development of observation and prediction capabilities, and studies of physical processes. In addition, ONR is supporting OPNAV N86 in studying the impact and design requirements for surface ship operations in cold region environments.
- Naval Research Lab (NRL): NRL-DC, Monterey, and Stennis are conducing and have proposed several environmental prediction efforts, including: (1) development of a coupled ocean-atmosphere model to assess variability with a focus on extreme events; (2) development of a seasonal prediction capability; and (3) development of a 0hr-30yr prediction capability for planning downscaled to regional/local scale. Elements of these climate related projects include exploration of physical, chemical, and dynamical processes; tropical-polar teleconnections/interactions; ocean and atmospheric (stratospheric and tropospheric) heat exchange and flux; air-sea-land-ice coupled modeling; space and upper atmospheric modeling and reanalysis; and fully coupled sun-Earth models.
- Naval Postgraduate School (NPS): NPS conducts basic and applied research and development projects on a wide range of climate topics, including: studies of the local, regional, and global atmosphere, ocean, and land; studies of specific phenomena (e.g., storms, floods and droughts, ocean circulation, sea ice process); long term data collection and analysis; climate model development and testing (e.g., statistical, dynamical, statistical-dynamical, multi-model, multi-decadal hindcasting and verification); climate system prediction (intraseasonal to multi-decadal lead times); performance prediction (e.g., prediction of sensor and weapons performance); operational impacts of climate change (e.g., impacts on infrastructure, sensors and weapons, personnel, planning—tactical, operational, and strategic, and national and international policy). Climate change is covered in several climate science courses, numerous other meteorology and oceanography courses, and also in operations analysis, national security, and defense analysis courses. NPS graduate students conduct masters and doctoral research studies on these topics and on the application of research and development results to the Fleet. NPS R&D addresses climate issues in the areas of responsibility for all the Combatant Commands.
- Naval War College (NWC): Individual student projects assessing the impact of climate change on National Security policy and planning, as well as scenario-based gaming with emphasis on Arctic operations and security over the next three decades.
- U.S. Naval Academy (USNA): Climate change science is covered in several courses within the Oceanography Department, and students conduct senior projects that involve climate-related factors.
- Naval Sea Systems Command (NAVSEA): NAVSEA is conducting assessments of cold region ship design in collaboration with Russia and Finland.
- Naval Facilities Engineering Service Center (NAVFAC ESC): Supported an initial assessment of Naval installation vulnerability in support of the 2010 Quadrennial Defense Review (QDR), supported a Central Command water study for the Horn of Africa region, participated in the TFCC-led Naval coastal installation vulnerability assessment, supports elements of SERDP's four coastal military installation assessments, and have proposed a study addressing the impact of climate change on coastal ecosystems.
- All of these organizations and efforts have included numerous publications and conferences, workshops, and working group meetings.

Charge Question 4: ***What do you see as the current requirements or demands for climate information from your Service that will drive the need for future research? (The goal is a list of future needs, research required, by whom.)***

Current Navy requirements for climate information exist on spatial scales from local to global, and on planning scales from tactical to strategic, to support development and implementation of mission/operational/campaign plans, infrastructure/facilities plans, education and outreach, policy development, development of Naval platforms, weapons, and sensors, and the investments associated with these efforts.

Improvements are needed in the climate science and climate information necessary for addressing these Navy requirements, including: (1) developing models with higher temporal and spatial resolution; (2) developing a range of model types (e.g., statistical, dynamical, statistical-dynamical, multi-model); (3) improving the physics in physical models of sea ice, ice sheets, the atmosphere, the ocean, permafrost, and coastal zones; (4) reducing and quantifying the uncertainties of these physical models; (5) providing probabilistic output from climate models and in climate assessments; (6) improving understanding of abrupt climate change scenarios and likelihood; (7) improving modeling of geoengineering deployment and associated global system response; and (8) addressing the wide variety of adaptation science interest areas for the Navy, such as improving surface ship/system operational performance in cold regions, and adapting coastal installations to sea level rise.

Charge Question 5: How do you envision your Service using climate information: are their new needs for research or information translation to support these efforts?

The Navy is using and will continue to use climate information to support: (1) development of tactical/operational/strategic plans and policy development; (2) the design, construction, and/or retrofitting of Naval platforms, weapons systems, installations, and facilities; (3) the sustainment of natural and cultural resources; and (4) the associated investment decisions required for each of these. Each of these require information regarding different physical processes (e.g. oceanic, atmospheric, and cryospheric), different spatial and temporal scales and resolutions, and with differing levels of confidence/uncertainty.

Although current Navy research efforts address these needs to varying degrees, new research is needed in: data access, management, and fusion; decision support; risk and uncertainty quantification; adaptation science; applications of operations analysis to climate change impacts/scenarios; and effective visual representation of climate data and predictions.

The greatest impediments to progress in supporting Navy climate change needs are the lack of availability of resources, educated personnel, and perception of the importance of climate change impacts on national security. Additionally, it is important to define the scope of climate change and climate variability for Navy research and applications. Some important elements to consider when defining this scope are temporal and spatial scales of variability, valid periods of prediction, rate of change (e.g., abrupt climate change), high priority regions, spatial and temporal interactions within the climate system (e.g., teleconnections), and geoengineering.

Several challenges impair effectively communicating climate-related information within the Navy, including challenges concerning climate education within the Navy component staffs,

sufficiency of resources and staffs to process and manage climate information, prioritizations concerning climate issues, and perceptions of the relevance of climate change challenges.

G3 Coastal Environments

Breakout Session 2
Cross-Cutting Theme 1: Regional Research and Development Needs

Group A – Coastal Environments
Session Chair: Mr. William Curtis, USACE ERDC-CHL
Assistant Chair: Dr. Edmond Russo, USACE ERDC-CHL

Charge: Coastal environments will be one of the most sensitive to climate change as they are exposed to the effects of sea level rise, potentially enhanced storm activity, ecosystem shifts, and salt water intrusion into groundwater supplies. Many DoD installations are located in coastal environs that provide valuable operational, training, testing, and ecosystem services in strategic locations.

Charge Question 1: What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure from local sea level rise, storm surge, and inland flooding during large precipitation events?

Physical processes that represent natural systems and hazards (i.e., forcing functions) at regional and local scales should be considered in the context of climate change. Beyond local sea level rise, storm surge, and inland flooding during large precipitation events, consideration should be given to physical process-based hazards including wind, sediment movement (erosion/ sedimentation), and constituent releases, movements, fate, and effects. The systems involved include:

- Coastal geomorphologic features (e.g., sandy shoreline/barrier island dynamics under wave/current forcings; vegetated wetland morphology under sea level rise and extreme event storm activity);
- Island systems;
- Coastal geohydrologic features (e.g., aquifer functions); and
- Ecosystem functions.

Increased knowledge is required of how climate change effects will transform coastal hazards (i.e., changes in probability distributions over time for such phenomena as coastal storm frequency/intensity; wave climates) and system drivers (i.e., increased constraints of uncertainties such as sea level change rates). In addition, understanding vulnerabilities and risks (i.e., what can go wrong) is needed for installation management and for natural systems and training under climate change drivers and hazards. Finally, knowledge also is needed on civil works infrastructure conditions and associated performance that installations depend on that also may be impacted by climate change.

Local data at installations that are required to support assessments include:
- Digital elevation models of sufficient resolution;
- Land cover / land use and attendant changes over time;
- Coastal water level data (e.g., waves, river flood stages, coastal storm surges, and tides);
- Water quality data;

- Temperature and precipitation patterns; and
- Ground surface movement information.

Charge Question 2: What technical needs are relevant to evaluating and distinguishing among alternative adaptation strategies for increased storm frequency and/or intensity for both built and natural infrastructure?

Improvements are needed in model coupling for computational efficiency and representation of non-linear/dynamic feedback of climate change, scenario-driver influences on quantification of solutions. Techniques for characterization of uncertainties that propagate through the assessment process are required for further development. The importance of using iterative approaches at different scales for alternative solution development and refinement must be emphasized and enhanced. Inventory of new climate change knowledge development (e.g., seasonal-scale variations in forcing) is required, beyond linking existing knowledge for executing vulnerability and risk assessments to support the ability to examine adaptations. The capability to work at multiple scales with existing methods/models and evolving them and the underpinning science are enablers that should be pursued. Significant improvements are needed in ecological modeling with guidance on how to sustainably assist natural processes in coastal marshes that can enable such marshes to keep up with sea level change. Coastal engineering guidance is needed on how to adapt designs of sea walls, revetments, etc., considering climate change effects. Identification is required on the tipping points in installation mission impairment that result in going from minor to catastrophic impacts, as well as for natural asset functionality.

Charge Question 3: What scientific and technology advances are needed to develop reliable predictions concerning future changes in coastal ecosystems under the combined effects of climate and land use change and how those ecosystem changes will affect military infrastructure, readiness, and operations?

Improved capabilities of earth systems instrumentation/remote sensing platforms and greater span of deployments for data collection are critical to enabling quantitative assessments. Increases in the amount of computing power available to DoD scientists would be very supportive for achieving enhanced model resolution and run cycle times. Methodological approaches to explore the effects of non-linear feedbacks of systems and process models on risk assessment are required. Environmental risks associated with abandoned and current military facilities are needed relative to liberation of contaminants.

Charge Question 4: What policy and technical guidance is needed for determining which climate and sea level rise scenarios should be used and at what spatial scales to drive risk assessment and response in coastal environments?

Definition of key decisions the military is contemplating that will enable scoping of technical assessments is required at the policy level. Technical guidance is required for quantitative risk assessment at installations globally, characterized as highly vulnerable to climate change effects, for identification of mission impairment tipping points and associated networked mission assets/capabilities. This guidance should be for systematic climate change risk reduction that is commonly occurring globally and uniquely occurring regionally/locally. Update of the Services' Unified Facilities Criteria (UFC) to address climate change scenarios for planning and

implementation should be informed in updates via such technical investigations that demonstrate these needs. Guidance on effective communication and technical transfer of information to installation management personnel will improve opportunities that new knowledge is employed in identifying adaptations.

G4 Cold Region Environments

Breakout Session 2
Cross-Cutting Theme 1: Regional Research and Development Needs

Group B – Cold Region Environments
Session Chair: CAPT Tim Gallaudet, USN, OPNAV/TFCC
Assistant Chair: Dr. Tom Murphree, NPS

Charge: Changes in cold region environments may affect DoD readiness and operations. The Navy in particular identified the Arctic as its near-term climate change concern, including possible changes in mission and required capabilities. Continued access to and use of training lands by the Army is contingent on permafrost conditions, which are subject to degradation under a warming climate. A relatively broad understanding of research needs has been developed for this region, but there are gaps in translating needed information into requirements.

Charge Question 1: How can science and technology developments from the research community be best transitioned to the operational level and into programs of record?

To best transition science and technology developments from the R&D community to the operational level and into programs of record, the existing programs designed for this purpose should be used. Examples of general DoD/Navy processes include OSD's Joint Capability Technological Demonstration (JCTD) process, the Navy Trident Warrior (TW) events for Fleet experimentation, and use of Joint Urgent Operational Needs Statements (JUONS) by the Combatant Commanders. Examples specific to environmental observation and prediction include the Naval Oceanography Enterprise's Future Meteorology and Oceanography Capabilities Program, Rapid Transition Program (RTP), the Administrative Modeling and Oversight Panel (AMOP), the Naval Oceanographic Partnership Program (NOPP), and the Oceanographic and Atmospheric Master Library (OAML).

Despite the advantages provided by these examples, improvements to the DoD acquisition process are required to speed science and technology to operational capability. Suggestions include: (1) leveling the playing field for all research performer organizations competing for R&D funds; (2) improving communication between the R&D and operational communities; (3) updating climate/environmental guidance for engineers; and (4) improving or developing new partnerships between the military Services and NSF, NOAA, other US Government agencies, and the scientific/academic communities.

Charge Question 2: What is the best mechanism to ensure operational planning documents and programs of record are informed on a regular basis by science and technology developments?

Research and development sponsors and R&D scientists and engineers need to routinely and frequently reach out to DoD planners (e.g., planners at the Combatant Commands, Navy Fleet Commanders, Air Force Major Commands, etc.) to: (1) inform them of science and technology advances and (2) determine if and how these advances can be applied to meet present and future operational needs. In addition, DoD educational organizations (e.g., service academies, war

colleges, NPS) need to educate future DoD leaders on climate change and its on-going and potential operational impacts. DoD R&D sponsors and researchers need to closely interact with each other to ensure that their efforts are well-coordinated and collaborative (e.g., coordinate and collaborate between Navy, Air Force, Army sponsors and researchers) to best meet joint and service specific operational needs. Finally, DoD sponsors and researchers need to intensively interact with their non-DOD counterparts to ensure that funding and research resources are effectively leveraged (e.g., so that DoD can quickly apply non-DoD results to DoD operational needs and avoid unnecessary replication of non-DoD efforts).

Existing examples of the methods exist that need to be applied. OSD's SERDP, USACE's Engineer Research and Development Center (ERDC), and the Navy's ONR, NRL, and NPS develop research guidelines and funding programs, conduct regular research, and/or coordinate with program managers and resource sponsors on a routine basis. The conferences and workshops that occur on a regular basis throughout the DoD, academia, and industry contribute to needed information exchanges (e.g., NDIA, SAME, ESTCP/SERDP). Several organizations and processes associated with DoD facilitate such information exchange, including the National Ocean Council (NOC), Defense Science Board (DSB), Naval Studies Board (NSB), State Department's Arctic Policy Group (APG), Center for Naval Analyses (CNA), U.S. Global Change Research Program (USGCRP), and National Research Council (NRC). All of these existing organizations have informed DoD programs on climate science and technology requirements.

Charge Question 3: What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure in cold region environments, in particular as a result of thawing permafrost, poorly understood coastal erosion processes, and altered fire and hydrologic regimes?

Several critical gaps exist regarding assessing and responding to risks to natural and built infrastructure in cold region environments, including: (1) sparse and incomplete environmental data sets (e.g. atmospheric soundings, digital elevation model, and hydrographic charts); (2) incomplete understanding of physical processes; (3) lack of skillful predictive systems for the physical environment; and (4) a lack of skillful downscaling methods. The physical phenomena that are most important but least understood include currents, sea ice, storm frequency and intensity, bathymetry, shoreline and geoid characterization, and permafrost.

Charge Question 4: What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive risk assessment and response in cold region environments?

Policy and technical guidance that is required for identifying climate scenarios and appropriate spatial scales for risk assessment and response in cold region environments include guidelines concerning the following topics: (1) anticipated DoD operating capabilities requirements for cold regions; (2) DoD operating thresholds or limits on operations; (3) climate vulnerabilities and sensitivities (e.g., of platforms, sensors, weapons, and personnel); (4) temporal and spatial scales for planning of DoD operations (e.g., operating periods, planning lead times, and planning regions); and (5) types, nature, and format for climate information to be used in DoD planning (e.g., deterministic and probabilistic predictions, prediction target spatial and temporal scales, and confidence and uncertainty supplements to predictions).

G5 Inland and Arid Region Environments

Breakout Session 2
Cross-Cutting Theme 1: Regional Research and Development Needs

Group C – Inland Regions, with a Focus on Arid Regions
Session Chair: Ms. Kelly A. Burks-Copes, USACE ERDC-EL

Charge: Climate change is expected to produce increased warming and altered precipitation patterns in inland regions, especially in the arid Southwest US. Even if mean precipitation increases, rainfall variability and cycles of drought and extreme precipitation events will likely increase. The preceding changes will affect the nature of flooding events, the quantity and quality of water, energy usage patterns, fire regimes, and ecosystem shifts.

Charge Question 1: What are the critical science gaps concerning climate change and land use impacts occurring within inland environments that are most relevant to military installations and their activities?

A round-robin exercise was undertaken to identify critical scientific gaps and the responses were aggregated in 3 main categories:

1. Policy and Guidance
2. Natural Systems and Resources
3. Infrastructure and Weapons

1. Policy and Guidance: Planning, Operations, Risk-based Decision Making all with regard to Climate Change Scenario Options
   a. Understanding of the very broad range of conditions in this rather large region is needed.
   b. How (particularly in the West) are the water rights & accessibility issues affected (assuming that the laws do not change)?[2]
   c. The dilemma of having agencies with multiple missions is that decisions regarding operations are based on the assumption that the water to support these choices is available. Do the agencies have the necessary tools to explore the vulnerability of the decisions given that water may be a particularly calamitous limiting factor?
   d. What do you use in (scenario- or projection-wise) in place of stationarity assumptions—what methodologies or strategies do you use that capture both spatial and temporal variations, with enough lead time to be effective and efficiently used in large-scale infrastructure planning and management activities?
   e. Planning for or simulating the probability of "events"—that is, storms (a variety of types: tornadoes, floods, blizzards, etc.) and their frequencies.
      i. How disruptive will they be on inland installations?
      ii. How do you prepare for events of a variety of "types" and frequencies/durations?
      iii. There are different types of problems to consider and the science and methods used to address trends in means with clusters or increased frequency of events.

[2]One participant noted that the Bureau of Reclamation has ongoing research on the 7 western regions (survey of regional climate data) & are beginning to look at climate change risk.

iv. The USACE doesn't "live" in the means of an event, but rather, focuses on the outliers—an increase in the frequency of these outlying events is of concern. And addressing the increased variability of these extremes is the priority. As a general rule, the area of numerical modeling/simulations do not work well in these "tail" areas—these are the events that really "bite you." The current models leave us particularly vulnerable because of these limitations.

f. How exactly do you "do" adaptive management; what steps do you take? Who's responsible? What is the analytical architecture needed to implement it?

g. There is a high degree of variability when you consider the breadth of this "region."
   i. Can we even consider developing tools that (even at the regional level) that can adequately capture/characterize the degree of variability of climate change response?
   ii. What is different about the regional precipitation patterns throughout the "inland" regions?
   iii. This is likely a problem with the way we (the Workshop Facilitators) framed the questions with respect to "inland" installations; however, as we get more arid, the climate and weather becomes more variable.

h. Risk-based strategy or structured decision making activities. Because of the magnitude and scope of uncertainty decision analytics need to be able to characterize or bound uncertainties in a meaningful and relevant manner.
   i. The farther you go up in the decision making chain, the problem becomes simplified.
   ii. How could you better preserve information in a useful form as the issue is elevated in the decision-making chain?
   iii. RAND robust-decision making is attempting to tackle this issue that could be incorporated—possibly tackling standardization (even maybe across all branches of the military).
   iv. Do we want to make decisions with a common toolset or BMPs?

2. Natural Systems and Resources
   a. River geomorphological processes and how it would be affected by climate change responses.
   b. The inter-relationship between the water available and the demands of wildlife is unknown or definitely a gap. Do we have tools or methods to make these connections and project forward the "sustainability" of the current or planned activities/operations of wildlife habitat?
   c. There are larger ramifications to the above. As human populations move nearby or encroach upon installations, how does this impact how we (the military) plan for and address the multiple demands for the same water, and how do we incorporate this into planning/management and how does this affect mission capabilities?
   d. Migratory patterns: will these be affected? Will they shift in response to temp/precipitation changes due to climate change? Ultimately this could affect BASH; it could affect operations and management.
   e. From the Navy's perspective one of the gaps for long-term predictions is a provision or insertion of aerosols so that when looking at the inland installations, can we begin to account for and predict when activities (increased dust or increased fires and the increased particulates released into the atmosphere). We need to develop methodologies to characterize and capture these potential inputs into the overall climate change scenarios.

f. If we can assume or predict species population trajectories, and how these might be affected by climate change (ecosystem response to), we need to begin discussion where the "hot spots" are, where there might be regulatory issues, and how these potential changes could be addressed in planning and managed over the long term.
g. Dispersal, establishment, extirpation. How will communities reorganize under future climate conditions? Animals have the potential to move or adapt to a point, but floral communities are likely to be significantly altered. Fire, drought, and invasive species will all become concerns.
    i. Do we have some climate change "canary" that we could use as an indicator? What happens when they get restricted to these "islands"?
    ii. If we want an indicator that is truly telling us about climate change, we need to be careful that we select species that are not necessarily sensitive to climate variability.
    iii. Because of the complexity, we are really talking about a series of hypotheses. "With this climate change scenario, we would expect to see x,y,z and by a Weight of Evidence approach we should be able to draw conclusions regarding planning and operational response."
h. Wetland status and implications for DoD in regards to wetlands: regulatory issues will arise; there will be a causation issue.
i. Contaminant releases: problems with assumptions of climate stationarity.
    i. What happens when soil moisture regimes change? Will contaminants be released?
    ii. Some sources of contaminants are known, but they currently lack receptors or pathways. Will this change under climate change and reduce the effectiveness of relying on natural attenuation as a remediation strategy?
    iii. Is there any way to forecast these problems in advance and proactively address these issues in advance?
j. Invasive species management: will these better adapted species be more tolerated? Some examples: Spanish broom, salt cedar. And will they be an impediment to training (e.g., yellow star thistle will increase and impede training).

3. Infrastructure and Weapons
    a. Heat is a concern—training and infrastructure—are they built to accommodate these anticipated changes?
    b. Need new projected floodplain mapping that incorporates climate change scenarios. This may not be possible given the current political ramifications. There is an opportunity here for DoD to assist the Federal Emergency Management Agency (FEMA) in their efforts and collaborate on stakeholder engagement and consensus building.
    c. When do we modify legacy weapons systems?
    d. How do we build in "climate change" into the decisions during the acquisition/ development process?

Charge Question 2: What science, engineering, or technology gaps should be addressed to advance our ability to inform decisions about the risks climate change poses to military infrastructure and training and testing capacity in inland regions?

See responses to ***Charge Question 1*** above.

Charge Question 3: What technology developments are needed to support military adaptation to climate change in inland regions?

Two more specific questions were devised in this session:

1. ***Do we need a new technology or engineering design to help the military adapt to climate change?***
2. ***Are there new technologies to proactively address droughts/floods?***

A second round-robin exercise was undertaken to identify needed technology developments. The following list was developed:

1. "Flexible" designs that have capacity built into them to address concerns of rain water storage, classic gray water usage, non-porous structures that can channel and pool water for reuse, and permeable asphalt to allow for infiltration. These technologies may already be available, but policy and guidance is lagging behind.
2. Natural infrastructure.
3. Weapon system improvements.
4. Dust.
5. Surface coatings.
6. Radar absorbing materials.
7. Pest management (vector-borne diseases).
8. Technologies that harden structures against forcings (i.e., strong-winds).
9. Soil conservation and erosion: are there some cheap, readily deployable additives that would stabilize soils, particularly in areas of heavy equipment and paratrooper drop zones?
10. Soil compaction in maneuver areas—maybe not?
11. Flood management: permanent structures are the status quo, but what about more temporary structures?
12. Biome shift models: prediction of rate/extent of biome shifts to facilitate habitat planning and T&E management or novel introductions or extirpations.

Charge Question 4: What critical gaps exist in scientific understanding, data, models, and tools in regard to assessing and responding to risks to both natural and built infrastructure in inland region environments, in particular as a result of extended drought, more extreme precipitation and wind events, and altered fire and hydrologic regimes?

See responses to ***Charge Question 1*** above.

Charge Question 5: What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive risk assessment and response in arid region environments?

A final round-robin exercise was undertaken to identify policy and guidance needs – the points were made:

1. We need it; we need scientifically-driven and defensible guidance & policy, tailored specifically to "where you're at in the 'decision-space' and how to incorporate climate change and environmental response into decision making." It should be tailored to the multiple decision-making levels.

2. Whatever the policy and guidance it is, it needs to be very flexible/pliable so that the design criteria and specifications can be adaptive as more information becomes available.
3. Our breakout group's challenge to upper management: "Just begin!" The installation-levels simply need to begin to incorporate a non-stationarity assumption of climate into their planning and management activities. This could then be refined through experience and progressive iterations.
4. New guidance should incorporate:
   a. Accepted levels of confidence & degrees of acceptable uncertainty.
   b. Planning horizons.
   c. Identification of credible emission scenarios to use and their sources (IPCC?) to generate anticipated x, y, and z environmental responses.
   d. What should "we" the end-user or installation manager incorporate? Temperature? Precipitation?
   e. Contractual qualifications/capabilities.
   f. Incorporate monitoring and iteration (adaptive management).
   g. Tied to the Master Plan or the EMS as a follow-on action.

Note to upper management: researchers and technical program directors need proponents. OSD support is needed for x, y, and z research to provide science input to policy development.

Researchers and technical program directors need broadly framed questions or concerns from OSD to prioritize research initiatives and programs given constrained budgets and resources. Investments are being made with limited policy input. Input is needed to optimize investments.

G6 Vulnerability and Impact Assessment

Breakout Session 3
Cross-Cutting Theme 2: Vulnerability and Impact Assessment/Adaptation/Climatology Research and Development Needs

***Group A* – Vulnerability and Impact Assessment**
Session Chair: Dr. Edmond Russo, USACE ERDC-CHL

Charge: Vulnerability of a military mission or of an installation's built and natural infrastructure to climate change is based on exposure (the location of concern is projected to experience some change in climate or an associated change such as sea level rise), sensitivity (the mission or infrastructure functionality would be sensitive to such a change), and adaptive capacity (degree to which the mission or infrastructure can or cannot accommodate to the change without significant functional impairment). Impact assessment considers a specific pathway of analysis that includes assumptions about climate drivers, whether probabilistic or scenario-based, environmental models, and impact assessment models, the last of which can be specific to military infrastructure, readiness, and operations. Having a clear understanding of potential impacts can provide a foundation for identifying necessary adaptation strategies.

Charge Question 1: What scientific understanding, models, and tools are needed to conduct vulnerability assessments of DoD installations, especially if such assessments are conducted as a high level screen across installations or regions versus within installations or regions?

Well documented and qualified scientific understandings about the climate changes that potentially impact DoD installations provide the foundation of performing skillful vulnerability assessments. The science must be able to clearly explain how and in what scenarios DoD installations could be adversely impacted by climate changes. Knowledge gaps about what is not well known must also be described for the purpose of understanding limitations in information applicability. Models that synthesize existing relevant data and input from subject matter experts about this science are often practical and expedient for use in characterizing the types, variability, and trends of climate changes in regions and at individual installations at the appropriate tempo-spatial scales. Tools that elicit value-laden responses of decision makers, based on this information are needed to distinguish on a relative basis and rank negative and positive impacts to mission functions and supporting assets/capabilities for individual installations. These tools should employ indicators for describing the following at successively higher levels in a framework that is able to cut across installation and command missions by type and by region geographically.

1. Ways an individual installation system state and its forcings could evolve with respect to potential climate changes.
2. Installation system performance limitations with potential climate changes and certain rates thereof, considering evolution in the system state and its forcings.
3. Current state of installation system stress in the prevailing climate conditions, considering any management activities already planned.
4. Synergistic effects of systems of installation systems, either by organizational structure/hierarchy, or by region, with regard to mission performance in these conditions.

Outputs should elevate the most certain and urgent potential losses and opportunities to sustaining performance of mission-critical infrastructure/training settings that are most effectively, efficiently, and expediently addressed via risk reduction and adaptation. Understanding is also needed on where to strategically focus investigative resources in successive tiers/iterations of vulnerability assessment, following the general approach described above, to scope where impact assessment is required within installation systems to sustain missions. Finally, identification of critical gaps in knowledge and understanding is an output requirement on climate science relevant to supporting future, continued vulnerability assessment.

Charge Question 2: What scientific understanding, models, and tools are needed to conduct comprehensive impact assessments for vulnerable missions and installations?

Comprehensive impact assessment, as it relates to climate change variability and extremes, requires the ability to describe systems scale performance in a probabilistic manner for objectives of interest from the present time into the long term, considering plausible future scenarios about key drivers with remaining uncertainties in scientific understanding. Thus, there must be sufficient scientific understanding to model the following in support of quantitative impact assessment at installations.

1. Projected changes in climate variability and extremes for the timeframes of concern at sites considered.
2. Characterized climate changes to the system considering current/planned practices.
3. Predicted changes in system forcings attributable to projected changes in climate.
4. Definition of boundary conditions under a changing climate regarding interaction with external systems in which the installation is dependent.

An inventory of science, models, and tools that are available with explanation of their strengths and weakness is needed by the impact assessment community to support this work. These include the following:

1. Science
   a. Focused on the rates of relevant climate change effects (e.g., saltwater intrusion, temperature/precipitation patterns/durations/frequencies) and system response, including non-linear feedback loops that change the system over time.
   b. Long-term (longitudinal) studies of natural phenomena of interest.

2. Models
   a. Climate/weather (accurately downscaled to a useful level).
   b. Hydrologic and hydraulic models.
   c. Sediment and constituent transport/water quality.
   d. Carbon sequestration.
   e. Fire.
   f. Ecological response models (e.g., species, communities, landscape-level).
   g. Infrastructure (e.g., networks & fragility).
   h. Economics/budget.
   i. Ecosystem services quantification.
   j. Energy/water consumption & usage.
   k. Integrated models.

3. Impact assessment framework tools
   a. Decision frameworks and strategies (e.g., drivers, stressors, pathways, response, endpoints, decision points, and turning points).
   b. Hardware/software/methodologies that take models outputs/observations and present/communicate them in a useful format.

4. Datasets with both sufficient temporal and spatial resolution as the environment changes to support modeling is also necessary, to include detailed:
   a. Topographical/bathymetric data.
   b. Geomorphology/soil properties.
   c. Land cover/land use.
   d. Water-levels and vertical land movements.
   e. Surface and groundwater hydrology.
   f. Weather, ocean, and ice formation.
   g. Ecological (e.g., species ranges, community functionality, landscape/patch dynamics & patterns).
   h. Infrastructure and anthropogenic activities information.
   i. Socioeconomics.
   j. Retrospective analyses.
   k. Metadata and data digests.

Charge Question 3: What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive vulnerability and impact assessments?

Policy and technical guidance should include those factors that will aide decision makers in advancing studies for identifying and acting upon potential for large-scale, frequent, and/or long-duration likelihoods of loss to installation mission performance, as well as strategic opportunities for exploitation in further advancing missions. These include:

1. Addressing treaties, laws, and agreements that must be informed for modification regarding long-term sustainability in the face of climate changes and their potential impacts.
2. Identification of decision making goals and objectives at the policy level and how those network to goals and objectives of installations and their missions.
3. A hierarchy of routine and long-term types of decisions required at various spatial scales.
4. Given prescribed time horizons and geospatial scales, specification on requirements needed to plan, operate, and maintain mission capabilities.
5. Update of Unified Facilities Criteria to address climate change issues.
6. Authority, methodology, and budgeting on how to evolve installation management and technical guidance, considering forcings that can be expected under given climate scenarios for current and future installation infrastructure designs.

Charge Question 4: How can science and technology developments from the research community relative to vulnerability and impact assessment be best transitioned to the implementation level and into operational practice?

For research activities to be highly relevant and richly successful in addressing climate change for installation sustainability, these activities would best be systematically integrated into the installation operations for deep, continuous engagement of their community of practice. This would sufficiently engage end-users for practically developing and implementing vulnerability and impact assessments that work to achieve aims. This should involve:

1. Developing a process for climate change-based installations operations research studies, pilot projects, documentation of lessons learned/best practices, and technical assessment product transition to the field (communication, training, support, guidance, resources & program).
2. Specifying in the Program Objective Memorandum the integration of climate change studies into current (established) policies & practices (e.g., Master Plans, Integrated Natural Resources Management Plans, Environmental Management Systems, etc.).
3. Incorporation of the science on addressing climate change issues into recognized accreditations (National Institute of Standards and Technology, etc.).

G7 Adaptation and Mitigation Science

Breakout Session 3
Cross-Cutting Theme 2: Vulnerability and Impact Assessment/Adaptation/Climatology Research and Development Needs

***Group B* – Adaptation and Mitigation Science**
Session Chair: Mr. William Goran, USACE ERDC-CERL

Charge: The science of adaptation in the context of climate change is nascent, though it can build on a rich understanding from the engineering, ecological, and physical science disciplines as to how human and natural systems respond to environmental disturbances and stressors. When faced with uncertainty about the potential impacts of climate change, improving the resilience to stress of DOD natural and built infrastructure can be a no-regrets adaptation strategy. Because the future may present novel climates, built and natural systems may be exposed to climate extremes and variability never experienced. For natural systems we need a deeper understanding of how they respond to dynamic environments and for built infrastructure we may need to consider new design tolerances. Adaptation and mitigation are linked and strategies to reduce emissions may have unintended consequences that affect adaptive capacity.

Charge Question 1: What scientific understanding, models, and tools are needed to advance the development of adaptation strategies?

Key discussion points:

- Decisions to manage built and natural infrastructure are being made regularly, so how can climate risk data be well integrated into these decisions? One needs a better understanding of the risks of not incorporating changes in the climate into our management decision processes—in terms of economic and mission costs.
- Adaptation implies adjustments in the face of new data, monitoring of vulnerabilities, and a nimble management capability to respond to data. How do we make our management framework more nimble? What management adjustments allow for more "adaptive" approaches in managing lands, facilities and operations?
- Strategies for adaptation need to work at multiple temporal scales—management usually focuses on short-term risks, whereas many risks from a changing climate are long-term.
- Methods and tools are needed to provide analysis of changing phenomena at various temporal resolutions. In addition, a framework is needed that works "backwards" from the projected timeframes when climatic changes are projected to impact operations and assets and determines the sequence of decisions and actions necessary to avoid or adapt to these impacts.
- Decisions should be robust in light of uncertainties. With infrastructure, some decisions (e.g., increased passive protection in light of anticipated increase in cooling degree days) will have no regrets regardless of the path of uncertainty, as extra insulation, triple pane windows, improved building envelope, etc. will only reduce cooling (and heating) demand. But other questions—should a building be moved or protected from storm surge and sea level rise—could be costly if anticipated conditions are greatly at variance from actual changes. So, tools that help decision makers understand "decision risk" would be helpful when reviewing investment or management adjustment plans.

Charge Question 2: What are the critical natural systems—whether they serve as protective barriers for other infrastructure or are needed for stewardship purposes—for which we need improved understanding of their dynamics under climate change to enhance their adaptive capacity and resilience?

Essentially all natural systems are impacted to some degree (must consider all of these holistically). Some systems are especially vulnerable to changing conditions, or at least they impacted sooner by changing conditions, to include: shorelines, coastal fringe systems, groundwater, hydrology, sea ice, coastal erosion, ice sheets, and arctic land surfaces (tundra, permafrost, and methane release issues).

As conditions change, dialogue is needed with regulatory agencies responsible for various natural systems, such as wetlands, endangered species, and protected marine ecosystems and species. In addition, the rapid implementation of renewable energy technologies, especially in these sensitive areas, is having and will have impacts on these systems that need to be better understood. Currently, these trade-offs are occurring without sufficient understanding of the system consequences. Finally, mitigation strategies are needed that provide feedback on the status of natural systems, which can inform adaptive decisions.

Charge Question 3: What design features of DOD's built infrastructure should be assessed and modified for improving their adaptive capacity to a changing climate?

Key Discussion Points:

- **Facilities:** Both new and upgraded facilities need to be designed for the climate that they will experience during their useful life, rather than the climate during the timeframe in which they are built. Engineering design parameters, however, have not been changed and a natural reluctance is present in the engineering community to change design parameters based upon "projections" rather than observations. To address this issue, investigations are needed to examine what approaches can be used to provide engineering data-based design specifications (e.g., such as cooling degree days) that meet engineering standards and also are responsive to both observed and anticipated condition trends. For the most part, facilities designed for changing conditions will be using less energy and providing more occupant comfort under any future scenario; as a result, the investments anticipating such changing conditions would be viewed as "no regrets" under most any future climatic scenario.

- **Utility systems:** Several circumstances need to be considered for utility systems: physical conditions such as temporary submersion, permanent submersion, increased water flows due to increases in storm frequency and intensity, and increases in duration and extent of high temperatures causing material stress. All of these stress conditions will be experienced widely by municipalities and other utility providers. Few will be unique to Defense organizations. In addition, there are load stresses that should be anticipated. These can occur with the electrical grid with extended high heat conditions over large areas with high cooling demands that may cause extensive overload conditions on the national and regional grids. In addition, flooding and intense storm events will overload many storm water systems. In addition to understanding where, when, and to what extent Defense utility infrastructures

(whether managed by Defense organizations or others) could be vulnerable to changing climatic conditions, Defense may also need to contribute towards helping to define the critical features of "climate resilient utilities."

- **Smart Planning at the Campus Level:** The new Uniformed Facilities Criteria (UFC) Master Planning guidelines call for smart planning, and they also may include language that calls for planners to anticipate and adapt to changing conditions, such as changing climate, using reliable and defensible sources of information. These guidelines include guiding principles for mixed use, smaller footprints, walkable campuses, and waterway protection, as well as many other planning approaches critical to military community resilience to changing climatic conditions. Smart planning needs to reach beyond the fence line in several contexts by engaging local communities in transportation options and waterway protection, water reuse strategies and storm water strategies, and engaging the code and regulatory community in planning design features that are flexible and adaptive.

- **Designer Material Features:** In terms of "designer" material features (e.g., features that would be designed into future materials but are not yet on the market) several characteristics could help build climate resilience into infrastructure: such as energy conserving features, environmentally responsive features (e.g., reacts and changes properties in light or dark, wet or dry, and cold or hot conditions), materials that combine strength, durability, and permeability (e.g., improve storm water flow while providing surface protections), and self-reporting and self-healing materials that have durability and resilience in changing conditions.

Charge Question 4: How can science and technology developments from the research community relative to adaptation be best transitioned to the implementation level and into operational practice?

Some of the approaches discussed include:

- **Integrating adaptation into operational decision processing:** One of the reasons for the "gap" between the R&D community and operations is that often no programmatic context is provided that moves science and technology beyond demonstration in environmental and facility infrastructure. One approach to help achieve this is to engage operational managers in demonstration review and then have them design the necessary steps to move beyond demonstrations (if deemed appropriate).

- **Consciously integrate "data, tools, science, and technology reachback" into operations:** Can new science and technologies be fully integrated into operations? Currently, most science and technology development occurs in a removed context, with some marginal input and engagement from operators, and is primarily accomplished by external parties. In addition, it usually occurs over a relatively short (2 to 4 year) timeline. Climate data need a longer timeline, and given the need to develop a resilient, adaptive framework to respond to climate (and other) stressors, it might be more effective to actually integrate a monitoring and decision framework that responds to data signals and provides tools (and expert reachback) to better examine alternatives related to these signals. This approach would start to "bridge" the science and technology–operational gap.

- **Tailor science and technology outcomes to better match operational needs:** Provide improved "packaging" guidance for science and technology outcomes, so that these outcomes fit directly into operational decision processes.

- **Interdisciplinary teams:** Understanding the "system" issues with changing climatic condition and complex system responses and interactions requires interdisciplinary teams. We often build interdisciplinary science and technology teams; however, transition success also will require interdisciplinary management team capable of understanding data signals and adaptation options.

- **Embed "bridging" persons into research and development (R&D) and operational organizations:** One of the more effective ways to "bridge" science and technology to operations is to embed R&D staff into operational environments to help with the transition of science and technology outcomes into management operations. The reverse situation—embedding operational experts into the science and technology development process, also should be considered.

- **Emphasize integrating new knowledge outcomes in operational training and in job solicitations and assessments:** Because of the challenges of adaptation, requiring effective multi-year collection and interpretation of changing climatic conditions and system response data, another approach to bridge science and technology outcomes into operations is to shape operational positions to have a stronger science and technology component.

- **Forums and partnerships:** Enhancing the dialogue between R&D staff and operational staff can happen in numerous venues, through social media, meetings, webinars, reachback, and informal discussions. Various mechanisms are needed to ensure effective communication and information flow between R&D performers and operational decision makers.

Charge Question 5: What is the best mechanism to ensure planning documents and programs of record are informed on a regular basis by science and technology developments related to adaptation?

- **Plan Updates:** Installation- and service-level plans are regularly updated. Opportunity exists, with each iteration of a plan, to capture new information; however, effective guidance and/or protocols to identify relevant new information and bring it into the new plans is not necessarily available. Because climatic conditions are changing, trends in weather events and new projections, relevant to the planning period, would be appropriate for numerous installation- and service-level plans, such as Integrated Natural (and Cultural) Resource Management Plans (INRMPs), Master Plans, Strategic Plans (to include Sustainability Plans), Critical Infrastructure Assessments, Training Plans at the installation level and Stationing and Readiness plans at the service level, etc. To ensure that new science and technology information is considered in plans, the R&D committees could "certify" specific types of relevant new information and present them in easy to use "packets" that are "plan ready."

- **Integrating planning criteria into planning and financial request systems:** One problem with financial requests is verifying that appropriate steps have been taken to follow planning criteria. Conceptually, planning and financial submission systems already seek to provide such verifications; however, more could be done to facilitate this process by integrating planning criteria into planning systems that provide users feedback on how well these plans conform to guidelines and planning criteria and by suggesting approaches to resolve or evaluate these issues. For example, the new Defense-level Unified Criteria Criteria for Master Planning has a chapter providing "Master Planning Philosophy and Strategies." These philosophies and strategies could be captured in a planning environment as a set of "criteria." Any plan could be evaluated against these criteria.

- **Links between multiple plans:** Plans interact, and military installations have structured plan team development and review processes to capture the linkages across plans. These steps are important, but plans could be "linked" in a more consistent and structured process, using such mechanisms as hyperlinks and "dependency measures" that trigger reviews across plans in a dynamic fashion that makes each plan more of a living document. This has been tested in some installation contexts; however, more work is needed to design, evaluate, and exercise such linkages and to change management operations to take advantage of these dynamic linkages. Although it is more complex, these same types of links could exist between installation- and service-level plans and also between deployment plans of units.

- **Dynamic planning environments:** One of the key capabilities to facilitate the integration of new data into plans is the development of more dynamic planning systems that provide for the feedback to users, linkages across plans, and stakeholder alignment evaluations to facilitate interactions between stakeholders. Such an environment can enable improved cross-factor sustainability planning and help illuminate the complex pathways and interactions across "systems" impacted by different engineering options, resource management approaches, and changing environmental circumstances.

Charge Question 6: What policy and technical guidance is needed for determining which climate scenarios should be used and at what spatial scales to drive the development of adaptation strategies, models, and tools?

This topic was not covered in group discussion because of the lack of time and a perceived overlap with other topics. This is an important topic, however, that does need to be addressed (perhaps in an ongoing fashion) by the report recommendations. Although some specific recommendations about where to find appropriate climate data and how to use these data for installation planning might be useful, a Defense science and technology resource (technical committee?) is needed to provide updates to this guidance and assistance in following the guidance. This committee would not be creating climatic data, but rather helping Defense organizations locate and apply climatic data from appropriate regional, national, and international sources.